

WORLD SUSTAINABLE BUILDING 2014 BARCELONA CONFERENCE



Sustainable Building: RESULTS

Are we moving as quickly as we should?

It's up to us!

**CONFERENCE PROCEEDINGS
VOLUME 3**



This is the third of seven volumes of the Conference Proceedings for World SB14 Barcelona, which took place in Barcelona on the 28th, 29th and 30th October 2014.

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***iiSBE:** International Initiative for a Sustainable Built Environment

UNEP-SBCI: United Nations Environment Programme - Sustainable Buildings and Climate Initiative

CIB: Conseil International de Batiment

FIDIC: International Federation of Consulting Engineers

World GBC: World Green Building Council



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Session 79:

How can we empower citizens to create an urban identity?

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Social sustainability between idealism and realism

Bushra Zalloom and Mohsen Aboutorabi

Abstract Summery

Political and economic aspects are shaping the built environment and transform the city identity. This transformation under the power of capitalism affects the social sustainability directly or indirectly. Cities play an essential role in expanding the opportunities for economic growth, innovation and social development; at the same time, they are also platform for poverty and threats. Thus, it is important to understand the logic of the dynamic processes and continuous changes in the cities. Decision makers should corporate to create new vision that recognize the city as a realm of play, creativity, and opportunities, and then try to balance between different aspects in creating the future identity of the city.

This paper provides a new vision in understanding the social sustainability; it suggests different perspective to comprehend the transformation on the city identity in order to enhance its sustainability.

Key words: *Social sustainability, City identity, City shaping, City transformation, Capitalism.*

1. Reshaping city identity under capitalism

City shaped organically without intended plans thus the product is unplanned city which reflect the political, social, and cultural features of urban life. However, as soon as it expanded, developed and attached to planned areas the whole identity starts to change (Kostof 2009), this transformation affects the social sustainability of the city. Some city managers, who are satisfied with the existing identity, try to localize its image through urban regeneration projects that preserve the local culture, while others, who are unsatisfied with the current urban identity, aim to transform its image to more globalized one that reflects power and prosperity. The created identity is mainly used in marketing the city worldwide and attracting investments as well as tourism, these contemporary approaches to urban regeneration in most cities are promoting images rather than sustainable concepts and process.

Political economy ignores the importance of spatial relations (Madanipour 1996), and successfully translated commercial interests into new urban form. In the global world, there is a risk of globalizing the identity, and therefore the loss of one's own identity. When promoting the city's identity, it is important to promote its uniqueness; that feature which makes it different. It is also important to make sure that the city's "true" identity is addressed and all the citizens' voices are heard (Barreiro et al 2009). Many researchers (Antrobus 2009; Kostof 2009; [Oktay](#) 2002; Lin 2010) argue that the identity of any city has depended on the connections it makes to the wider world. In the contemporary era of globalization, the identity of the city is also important in creating connections. City managers who seek to transform



their cities, therefore, must understand how their place is seen in order to attract flows of resources (Antrobus 2009).

The political and economic aspects play a critical role in transforming the urban identity and redefining the meaning of urban space. Major change happens in the beginning of 21st century and accelerates the cities transformation is the economic crisis. It “has already had serious consequences on employment and public budgets” (EU 2011:91), and affected the physical, social, cultural, and governmental aspects in different cities worldwide. The transnational mobility of capital has brought about specific forms of articulation among different geographic areas - including Jordan and the Middle East- “where investment is made in the built environment, creating a whole physical landscape for the purpose of production, circulation, exchange, and consumption” (Madanipour 1996:17), and where the capitalism ideology has its own logic in remodeling the world; according to its own partial view (Summer 2005). This partial view increases the spatial segregation and the social polarization; thus harms the social sustainability.

Identity is a very complex concept that involving a variety of factors, and building a new identity is not just about recovering the past or its heritage, but to an extent it determines the city’s future. Accordingly, the following sections look at different concepts of building city identity in a creative manner through urban regeneration projects to enhance the social sustainability. In the global world, the image of city no longer reflects the identity of place since the same pattern of development, the same architecture of high rise buildings, and the same cityscape with no reference to locality is repeated worldwide. This approach has contributed to dullness where most cities becoming an imported image with no identity. This sameness or placeless identity harms the social sustainability. Accordingly, the traditional meaning of the city should be changed, and identity might be better understood through the changing role of the city. Cities should be reshaped and reimaged to address the needs of the new companies, thus it can be seen from different perspectives as hubs for creative industries and business, or as spaces for consumption, or as realms for play.

1.1 Cities as hubs for creative industries and business

In the late twentieth century, large cities have emerged as a strategic site for a whole range of new types of creative industries. Creative industries, such as architecture, software, craft, design, music, advertising, and other telecommunications, play a critical role in creating identities (Farrow 2009). Massive developments in telecommunications and information industries led professionals to declare the end of cities. Cities, according to them, would become “instants in a global space of flows where space and time are compressed, and where the world is shrinking” (Madanipour et al 2001:26-27). In other words, the globalization of economic activity suggests that the type of places represented by cities no longer matters (Sassen 2001).

The growth of creative industries, such as information technology, allows firms and workers to remain connected no matter where they are located. The digitizing of services and trade shifts many economic transactions to electronic networks, where they can move instantaneously around the globe or within a country (Sassen 2006). In other words, the emergent globalization of economic activity seemed to suggest that the meaning of cities in a global and increasingly digitized age is one of the challenges of the new century (Friedmann



1986; Castells 1989). Antrobus (2009:8) argues that all transformations are about how connections are made to spaces beyond the city, as many people think of the city “as container” and that governing a city is about managing what is inside the boundary. However, what is needed is a spatial imagination to see the city as a place where wider flows of money, people, and materials settle. This means that a city is not only a “space of place”, but with the rise of global interactivity it becomes a “space of flows” (EU 2011:52)

These processes have been reflected in new spatial and social formations, and reintroduced place in the analysis of major nonurban dynamics. Madanipour et al (2001) argues that new information technologies have normally acted as an enhancement to human communication rather than a replacement. However, over the past twenty years the nature of everyday urban life has been extremely affected by the global developments in telecommunications and information industries. It is not only affect the direct face to face communication and socialization, but also increase the importance of different services such as financial services, banking, marketing, public relation, and retail sector. This has been also coupled with social and demographic forces, increase of unemployment, and the rise of a new bourgeoisie.

This acceleration of everyday life and revolution of creative industries always associated with a failure of identity. Still, the success of the city’s identity will depend on sustainability, as it involves defying a new urban model to create more inclusive and sustainable communities (Barreiro et al 2009). This model should respect the political, economic, social, and cultural dynamics and fulfill the developers’ needs for global communication and the locals need to identify their uniqueness in this global world.

1.2 Cities as spaces for consumption

Recognizing the city as a space for consumption is a different concept of identity which mainly anchored with urban regeneration projects that characterized by office towers, high-end shopping malls, and entertainment areas (Sassen 2006). There is much theorizing about how consumer habits and forms of socialization have taken place in Western societies and affect their identities (Abaza 2001), which means “that everyday life produces a new kind of culture, where membership is marked by paraphernalia (clothes, taste, music, fashion, etc.) and spontaneous structuration in localities” (Jayne 2008:71); this new kind can be called a *consumption culture*.

Mark Jayne (2008) in his book “*Cities and consumption*” states that; the most successful cities contain the most culturally and socially diverse and innovative spaces of consumption. According to him, the new urban spaces that associated with *consumption culture* are eclectic in styles, spectacular, spatial fragments designed for aesthetic rather than social ends with playful landscape. The spectacular shopping malls, for instance, are considered to be the most recognized space of consumption. Many researches (Jayne 2008; Abaza 2001; Lin 2010) explain that the historical meaning of urban form can be combined within the spectacular shopping mall, which is a new wave of commercial malls represents a coming together of cultural, demographic, social and spatial factors associated with global city. For example architectural designers collapse traditional concepts of urban form by gathering together all of the social amenities and shopping experiences of the “traditional” down town city street to the suburbs, by playing with space and lights, representations and perceptions of safety. City streets, squares, plazas, markets, in many respects the defining sites of urban circulation and

exchange, could be carefully included within the walls of the shopping center and re-imagined as idealized public spaces, free from inconvenience of the weather, traffic pollution, and “unwelcome juxtapositions constituted” through the presence of poor people or “threatening” ethnicities (Jayne 2008: 80). The design of “Ibn Battota mall” in Dubai is good example for that trend, it offers a world within a world, and is fantasy landscape contrasting a historic present and past through themed streets and squares, while a Mall remains a castle and protected (Fig. 1).



Fig. 1- Ibn Battota mall in Dubai is an example for packaging heritage and selling them in the present, it offers a world within a world (Source: the researcher)

Abaza (2001) in her study about shopping malls in Egypt showed that consumption has become a world of its own. She also highlights the importance of space for consumer identities as well as the cultural practices of shopping. Moreover, she pointed how the new urbanity is constantly creating new forms of social relation and lifestyle (Abaza 2001). The study shows that the shopping malls in high class districts in Cairo, provide the most expensive and lavish buildings, illustrate how classy people do their best to keep the masses away by tightening their security and introducing expensive restaurants and coffee shops that will exclude the poor (Abaza 2001). By the same token, these shopping malls incorporate a new conception of space for leisure (cinemas, shops, fitness centers, computer games with communication facilities), and represent new way for the middle class, of occupying space



and spending time. In contrast, Oksana Mont (2008) claimed in the report of the “*Sustainable Consumption Research Exchange (SCORE!) Network*” that there is a big chance to change these values towards non-consumption lifestyle. She argues that there should be a shift from a class-based modern society to a fragmented consumer society, and suggests that a departure from collective consumption should take place.

As a result, urban populations are now divided by life style rather than social class, gender, race, and ethnicity. Spaces of consumption, whether pedestrian streets or shopping malls, have been transformed into playgrounds for new forms of activities, where individuals can confirm their existence through consumption. This created a collective sense of belonging based not on social class or kinship but on lifestyle and consumption.

1.3 Cities as realms for play

The concept of play embraces many of the forms of urban social life; play is a lived critique of instrumentally rational action, because it discovers new needs and develops new forms of social life. The kind of social practices which can be labeled as “play” are a fresh lens for viewing urban sittings and understanding their performance, and what counts as a “playful” behavior clearly varies between and within cultures.

Lefebvre (1996) and Stevens (2007) among others linked between cities and play as both have the richness and intensifying of sensory experience, the intimacy and solidity of urban experience. The city assaults all the senses continually, awakening a wide range of meanings and desires. The experience of urban space is characterized by diversity, uncertainty and contradiction, the unpredictable and the unfamiliar. In these ways, urban public space provides a special realm for play (Stevens 2007). In addition, urban experience and social needs can be understood by looking at everyday life on the streets, at the meanings it might have for those who live it, and at the complex tensions which arise between different needs, different meanings and different users in space (Lang 2005, Zalloom 2010).

Similarly, Wirth (1996) defined the urban condition as “a relatively large, dense, and permanent settlement of socially heterogeneous individuals” (Stevens 2007:5 citing Wirth 1996). But this expression still undermines the important of interactions among these diverse individuals, which really creates urbanity, and which produces livable space. Urbanism without a certain degree of interactions is just a mass of completely unconnected, alienated strangers. Stevens (2007) highlights the importance of interaction among individuals when he discusses the everyday life, and the special characters of life in urban public space, as a setting for people’s experiences and actions, he focuses on two main elements: the particular dynamic of urban social relations and a phenomenological account of urban spaces as perceived by people who use them. The experience of urban space is characterized by multiplicity, ambiguity and contradiction, the unpredictable and the unfamiliar. In these ways, urban space provides a dynamic realm for play.

Theorists identify social practices of play as a key to understanding the dynamic tensions which shape everyday life in public spaces. Stevens (2007) discusses this realm for play in his book “*The ludic city: Exploring the Potential of Public Spaces*” by describing the everyday life. He states that Leisure becomes confined to specific, separated spaces such as cafes which reinforce and reproduce bourgeois values and social relations, he analyzes different case studies according to locations where play has been observed: paths, intersections, thresholds,



and boundaries. He states that the richness of sensory experience, the closeness and concreteness of urban experience is a linking theme between cities and play. Jayne's (2008) opinion alike Stevens' in the importance of studying the everyday experience which is characterized by diversity, uncertainty and contradiction. Urban conditions shape particular dynamics of spatial behavior, sensory perception, and needs, closing with an examination of the role of leisure within everyday urban life. The concept of play constantly emerges within this discussion as a key aspect of urban experience (Lefebvre 1991, Stevens 2007).

Play is not a fixed phenomenon, it means different things to different people in various situations, and its potential is continuously changing in space overtime. It cannot be reduced to a specific set of experiences as it takes its shape according to various physical sitting. Therefore, if people recognize the city as realm for play they will accept the transformation of the built environment because it enriches their daily experience.

2. The potential of diversity

A study prepared by the United Nation in 2005 which aim to shedding light on the role of development in shaping the character of the Arab city, this study consists of a comparative analysis of three case cities, namely, Amman, Beirut and Dubai, which have drawn attention for the significant changes in their economic, social and physical dimensions. The United Nation study finds that diversity and difference provided a multicultural life of various intensities in the three cities. Among the three cities, Amman is the city that has undergone the most qualitative changes; Beirut is the oldest continuously inhabited; and Dubai is the most economically vibrant. This confirms that diversity and continuous change can be considered as part of the city identity and part of its uniqueness.

Much depends on the perspective of diversity, and whether we regard the city as a container of problems or as a place of freedom and creativity, a realm for play and joy, a place for opportunities rather than threats. Within this view of diversity, we may recognize that the effect of new developments on city identity is very limited. Urban identity is more than the architectural style or the buildings form; it is the collective memory of place, its people, topography, and skyline. Thus, the identity of the city is renewable; it has some fixed elements anchored with spatial characteristics, traditions, values, relationships, while the way how these fixed elements are presented on ground is changeable to suit the continuous development of life, and to confirm people's ability to sustain. This new vision to identity helps us to absorb various changes and enhance the logic of sustainability among people.

We also have to admit that contemporary society is more fragmented and controlled by the power of capitalism; this is a rational product of the existing regulations and of globalization as well. The degree of inclusion for spaces decreased by time, with or without these developments, the fast rhythm of daily life affect our social behavior, and new means of technology and communication enhancing this phenomenon. Different means of communication through internet and social media replace the social activities and physical gathering in one space. Virtual reality transforms the logic of socialization especially among young generations, thus the challenge is breaking the segregation and turning the diversity into a creative force for innovation, growth and well-being in order to enhance the logic of social sustainability.



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Local GREEN PARTNERSHIPS for greener Cities and Regions

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Mediterranean cities and regions have adopted local energy strategies to achieve the goals for increased Energy Efficiency (EE) and promotion of Renewable Energy Sources (RES), set by the Europe's Energy strategy for 2020. However a fresh approach is needed since the implementation capacities are not sufficient to meet the set goals.

GREEN PARTNERSHIPS project (GPs), links 11 MED regions and is working on specific recommendations and solutions to overcome the obstacles the local authorities are facing by enhancing their competences and establishing local partnerships leading for greener cities and regions, which are resulting in long-term improvement in behaviour, increased technical and organisational knowledge, substantial savings in energy use and in new investment proposals.

The main benefits are the contribution to the local communities' empowerment in a new energy culture, based on less intensive use of energy and GHG emissions, improved energy efficiency of buildings, installations, and increased use of RES.

Sustainable energy planning, sustainable development, green cities, energy efficiency, local energy strategies, local green partnerships, governance models, community empowerment, capacity building, knowledge transfer, local action groups.

Introduction

GREEN PARTNERSHIPS project (GPs) aims to strengthen the implementation of local public policies and strategies related to energy efficiency for sustainable local and regional development of the MED cities and local communities by:

- developing a joint innovative approach including the development, promotion and testing of operational recommendations for overcoming the existing difficulties faced by local public authorities,
- enhancing the local capacity and human resources competence,



- boosting cooperation of stakeholders in implementing energy efficiency measures by establishing local partnerships.

Through an innovative dimension, GPs is developing a new integrative approach for more efficient implementation of local energy strategies by forming local Green Partnerships. GPs are formed between local public authorities and stakeholders of the energy chain (including owners, investors, suppliers and final users) relevant to the measure or energy management scheme to be implemented. The decision-makers and public personnel are expected to use the new approach, as a combination of top-down and bottom-up proposals, which has several positive contributions to the management and operation of public authorities and the implementation of energy strategies in cities and regions.

These capacity building and knowledge transfer activities for decision-makers are manifested by forming Local Action Groups (LAGs) created in 11 participating countries (Slovenia, Cyprus, Greece, Italy, France, Portugal, Spain, Albania, Bosnia-Herzegovina, Croatia and Montenegro) by an interdisciplinary multi-stakeholder approach. LAGs main role is to provide expertise and support during the pilot actions implementation in each respective city/region and to ensure that all different aspects within the community are heard and taken into account. LAGs composition includes representatives of the interested key stakeholder groups (decision makers, researchers/experts, market actors, technology/service/product providers, consumer/citizens associations, financial organisations) and LAGs are coordinated by the national responsible partners.

Additionally, as a key to the knowledge transfer expert working groups have been configured aiming to support the transnational exchange of knowledge in the areas of energy efficiency and renewable energy sources, the preparation of common guidelines and monitoring systems, which will be included in the final Step-by-step manual for efficient implementation of local energy strategies, and enhancement of the local capacity for sustainable energy efficiency projects and investments.

Finally, 22 pilot projects, addressing specific needs of the local communities have been selected and are put in action to increase energy efficiency and use of RES and to prepare feasible technical solutions for future investments in the 11 GP cities and regions.

Enhancing more efficient implementation of local energy strategies

Green Partnerships consortium aims at supporting local administrations to overcome existing obstacles and to effectively implement appropriate measures on the way to energy efficient cities and regions. The goal of the initiative is to establish a common transnational approach that may contribute to a more efficient implementation of innovative energy efficient measures and RES solutions leading to sustainable local and regional development.

Under this scope, 8 different Expert Working Groups (EWGs) were established with the aim of facilitating knowledge transfer between experts, the project partners and members of the Local Action Groups, enabling transfer of best practices between regions and spreading the



knowledge to the identified priority thematic areas as follows: Biomass, Solar Energy, Energy Efficient Buildings, Public Lighting, Funding, Legislation, Awareness, and Stakeholders Involvement.

The training materials prepared from the EWGs aim at providing technical knowledge on key energy efficiency and RES technologies, good practices inherited from public authorities across Europe, useful resources and links for further information and guidelines on how to address existing obstacles in implementing local energy strategies in the above thematic areas. The training material is going to be adapted to the local needs in order to support the implementation of local/regional capacity building workshops, targeted to representatives/staff of the local/regional authorities and public bodies and/or other Local Action Groups' members. Prepared guidelines aim also at increasing knowledge of partners for implementation of pilot activities and exchanging experiences and best practices between more and less experienced partners in certain thematic areas – to work directly on the pilot cases and to find solutions that were already effective in similar situations.

EWGs have developed appropriate materials to be used as training materials for the local/regional capacity building workshops after adaptation to the national/local conditions and to the national legislative and technology frameworks. In each Green Partnerships country, capacity building workshops are implemented to enhance the local capacity with regard to the pilot projects' thematic areas.

EWGs will also provide partners with the basic content and technical information, as well as a number of existing best practices and further resources/links to cover the specific topics in each thematic area. The common approach starts with discussion, related to environmental and economic impacts. The result is a basis for feasibility studies or implementation strategies (depends on pilot cases or idea, developed by local partnership). The choice between different options should take in consideration also social impacts on society or municipality. These three factors result in sustainability and cause win-win situation in implemented thematic areas. Collaboration within local partnerships is expressed with the decision about the type of cooperation, quality criteria and the kind of contracting. Technical details are not the most important since the basic decision about the source of energy is accepted in community and recommended by local energy strategy. They are important for ordering of equipment and are defined by the investor. Common recommendations about emission rates and other features are usually prepared by regional or local regulations.

Capacity building and knowledge transfer in the Mediterranean cities and regions

Within the Green Partnerships initiative priorities is to promote the cooperation between public and private entities aiming to efficient local partnerships, as well as to transfer technical knowledge and to build capacity of the stakeholders involved, in order to

- empower local capacity and to enhance understanding in energy efficiency and sustainable development
- to inspire through best practices and

- to address common barriers in the implementation of sustainable energy action plans.

Acknowledging the value of the stakeholders’ consensus and support for the efficient accomplishment of the local Sustainable Energy Plans, Local Action Groups (LAGs) are established through an interdisciplinary multi-stakeholder approach in each of the 11 Green Partnerships countries (Slovenia, Cyprus, Greece, Italy, France, Portugal, Spain, Albania, Bosnia-Herzegovina, Croatia and Montenegro).

LAGs actively involve 121 members and more than 85 organisations, representing the interested key stakeholder groups in the pilot areas (i.e. decision makers, public authorities, researchers/ expert market actors involved in energy efficiency sector, technology/ service/ product providers, chambers, consumer associations) with a common vision to achieve the local Sustainable Energy Plans targets and to propose improvements for their existing energy strategies.

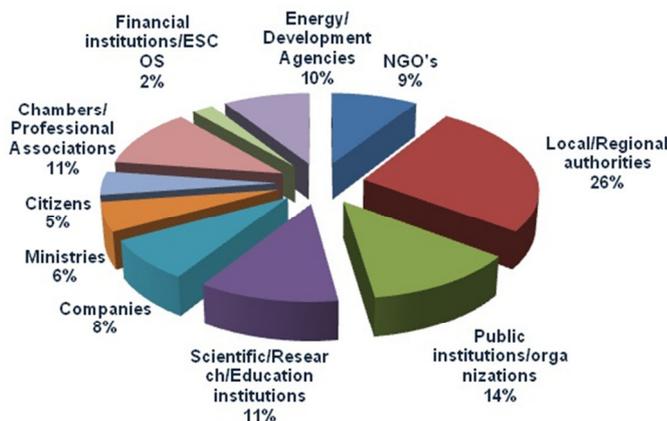


Figure 1: Synthesis of the Local Action Groups members (LAGs) in the Green Partnerships countries

LAGs work at local level aiming to prepare local step-by-step plans for capacity buildings and to test the measures of local strategies in their pilot activities. Their role is to provide expertise, to support the pilot projects’ implementation and to ensure that the actual community’s needs are taken into consideration. The interaction between LAG members revealed common opportunities and similar barriers that local authorities face during the implementation of their local energy plans.

On the above basis, with an emphasis on creating capable local partnerships, the Green Partnerships consortium has organised 22 Capacity Building workshops (two workshops per participating region), targeted to decision makers and to the staff of the municipal / public organisations’ technical departments. The Capacity Building Workshops aim to enhance the local capacity with regard to the pilot projects thematic areas and to provide the participants knowledge in RES and energy saving technologies as well as understanding in the areas such as legislation, funding, communication and stakeholders motivation and guidance on the steps that need to be followed to implement efficiently sustainable energy projects in their region.



During the workshops, participants are informed about methodologies/applications/solutions which might be applicable to the local SEAPs and foreseen pilot cases, critical economic and technical considerations which may affect the decision making process, legislation issues and existing examples or best cases from relevant applications in the public sector across Europe.

With gained knowledge, increased competences and innovative approaches, local authorities will improve their energy strategies and will be empowered to effectively implement these strategies in their local communities, assuring their sustainability.

Pilot implementation of selected measures and technical solutions for future investments

In order to apply the developed common approach, in each participating country 1-4 pilot energy efficiency measures have been implemented. Within the pilot projects, each local partnership has prepared new technical solutions and tested the developed approach in order to overcome existing obstacles that have hindered the implementation. Local partnerships have been established on the basis of the step-by-step plan prepared by LAGs and have taken into consideration all opportunities for local communities and build an integrative way for the solution of the problem to achieve a long term effect for the local community.

The objectives of the project have been carried out using different measures and soft approaches (workshops, match-making events and public roundtables) as well as technical improvements and installation of pilot energy efficient equipment.

In each partner region, the following actions are taken:

- establishment of the local partnership,
- pilot implementation of selected measures in cooperation with local partnership,
- preparation of the technical solution for future investment or business cooperation.

On the basis of the plan prepared by the Local Action Group the local partnership has been established and consist of:

- decision making group (local or regional authorities, and other relevant organisations, e.g. local energy agencies),
- potential investors,
- end users, consumers, citizens,
- other stakeholder (e.g. different kinds of private-public partnerships including financing entities, technology/equipment providers)
- technical staff (engineering companies, architects, experts on the specific EE measures).

Awareness-raising campaigns and know-how exchange aim at improving local policies concerning use of local available renewable sources, efficient use of energy in public buildings and saving of energy in Mediterranean cities and regions. It has been proved that all members of local communities have a key role in supporting local authorities to address the energy and climate challenges. For the efficient implementation of any energy efficiency measure the citizens' awareness, consensus and support is critical for the achievement of the

targets set. Young generations in schools and kindergartens are also a key target group where the change of energy behaviour is crucial.

In the next table are presented the measures implemented in pilot activities and the expected results.

Pilot case area	Description of measures	Expected results
Maribor-Slovenia	Energy efficiency in old cultural heritage building	Investment proposal for efficient use of energy with different scenarios
	Renewable energy: Biomass heating contracting in public buildings	Two investment proposals for biomass heating boilers in 2 public buildings
Lakatamia-Cyprus	Renewable energy: Biomass heating for swimming pools	Investment proposal for biomass heating system in swimming pools
A3V- France	Renewable energy: Territorial biogas project	Investment proposal for biogas power plant using innovative stakeholders involvement approach
	Renewable energy: Hydro power plant	Implementation of a hydro power plant on an irrigation canal
Rethymno Crete - Greece	Energy efficiency interventions in open space – Green neighbourhood	Feasibility study for the bioclimatic design of the open space in an urban area
	Energy efficiency in public lightning	Implementation study for efficient public lightning in historic city centre
	Energy efficiency improvement of the water pumping and treatment system	Technoeconomic study for the energy efficiency improvements of the water pumping system
Province La Spezia- Italy	Strengthening of local public-private partnerships in supporting energy efficiency and RES	Establishing new Information's centre, called Environment and Energy centre
	Energy efficiency in schools	Raising awareness and preparing of preliminary studies to be involved in ELENA and MLEI
	Mobilisation funds for investment in sustainable energy at local level	Mobilisation of decision makers, exchange of experience
	Energy certification	Training civil society using web platform tool and wide range of stakeholders engagement
North Alentejo-Portugal	Energy efficiency in municipal buildings	Improvement of interior lighting systems in municipal buildings
	Energy efficiency in municipal buildings	Installation of capacitor batteries for power factor compensation

Granollers- Spain	Energy saving in public buildings	“Championship for energy saving”
	Energy management in public buildings	Installation of remote control systems in public buildings
	Energy efficiency	Feasibility study on the installation of trigeneration combined with self consumption and provision of energy services
Manza- Albania	Renewable energy sources for schools and kindergartens	Awareness rising and training courses for young generations
Sarajevo- Bosnia and Herzegovina	Energy efficiency in households	Feasibility study on creation of support fund for energy efficient housing
	Energy efficiency of public buildings	Awareness rising campaigns in schools and public buildings administrations
Koprivnica-Križevci, Croatia	Renewable energy sources	Creation of possibilities and investment proposals for installation of biomass boilers, biogas power plants and photovoltaic panels on public buildings
Podgorica- Monte negro	Renewable energy sources	Feasibility study on installation of hydro power plants in Monte negro

Table 1: Pilot cases in the Green Partnerships regions: measures and expected results

Expected results

The project will result in improved public policy related to energy efficiency in participating cities and regions, new investments and energy savings of up to 40% in public facilities, increased capacity of public organisations and long term cooperation of local partnerships for energy efficient solutions. The main results foreseen are:

- showcase of existing models and best practices on implementing local energy strategies,
- a step-by-step Guide for efficient implementation of local energy strategies by forming local partnerships,
- 11 Local Action Groups formed and 11 step-by-step plans for capacity building and efficient implementation of measures from the local strategy,
- 22 capacity building workshops to enhance local authorities’ competences,
- improved local energy strategies in 11 participating regions to boost future energy efficiency activities and investments financing in cooperation with local partnerships,
- 22 pilot activities implemented, 22 local partnerships formed in the 11 pilot areas,
- 45 events for local partnerships, actively involving 121 members and more than 85 organisations.



Conclusions

The European strategy for 2020 promotes smart, sustainable and inclusive growth. Regional development and implementation of local energy strategies in the field of energy efficiency and RES play a significant role in achieving the Europe 2020 goals. The European initiative 'Green Partnerships' aims to support public bodies in Mediterranean cities and regions to overcome the obstacles faced during the implementation of Sustainable Energy Plans.

The main benefits of the Green Partnerships project are the clear contribution to governance models and tools and, at the end, the community empowerment in the area of a new energy culture, based on less intensive use of energy, reduction of GHG emissions, increased energy efficiency of new and existing buildings and installations and use of RES.

Eight different Expert Working Groups (EWGs) have been established with the aim of facilitating knowledge transfer between experts and the project partners; enabling transfer of best practices between regions; providing guidelines on how to address potential obstacles in implementing local energy strategies in specific thematic areas; preparing appropriate training materials and increasing knowledge of partners for implementation of pilot activities and exchanging experiences and best practices between more and less experienced partners.

Representing the key stakeholder groups in the pilot areas 11 Local Action Groups have been created in all participating countries, which actively involve 121 members and more than 85 organisations, with a common vision to achieve the local Sustainable Energy Plans targets and to improve their existing energy strategies.

Each of 22 pilot cases builds private public partnerships with emphasis on local supply chains, which ensure energy independence as well as new working places and development of Mediterranean regions and cities. Established cooperation between public and private organisations and final users is resulting in long-term improvement in behaviour, increased technical and organisational knowledge, substantial savings in energy use and in new investment proposals.

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Understanding residents' attitudes towards infill development at Finnish urban suburbs

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Abstract: *Urban infill development is an important strategy for more sustainable cities. At the same time, there are a number of impediments for the use of this strategy. Resistance from residents' is one of the most important ones. Thus, understanding residents' thinking and psycho-social basis of their reactions is essential for successful infill development.*

The purpose of this research is to create understanding about the basis of residents' attitudes towards the idea of infill development in their neighbourhood. The study targets 23 suburbs with potential for infill at Finnish capital area. The sample consists of survey answers from 906 residents who own their apartments. The results suggest that residents' concerns about any negative changes in the neighbourhood, and especially those relating to unique identity of the area and nature amenities are among key beliefs contributing to their resistant attitudes, whereas anticipated better services and public transportation, contribute to positive attitudes.

Infill development, resident, attitudes, beliefs

Introduction

Infill development and urban densification are generally considered as key means to restrain the adverse effects of urban sprawl as well as a way towards more sustainable cities [1].

However, planning and actualising infill development faces many challenges. Among them are problems of land acquisition and residential opposition [2][3].

City planners seek to achieve a range of ecological, social, financial and functional benefits and counteract the disadvantages of sprawl with infill development. It is believed to reduce travel demand, produce liveable communities and improve resource efficacy [3][4]. The financial resources saved provide cities more possibilities to make improvements influencing the living quality of local residents. Thus infill development often also aims to improvements in services (or at least retaining them), in public transportation and in availability of other amenities close to home e.g. [5]. Also, better social interaction, social cohesion and vibrant and revitalised communities are sometimes expected to result from infill. New, higher standard houses with pleasant architecture can attract wealthier inhabitants and all these together result with more valued neighbourhood with better reputation [6]. In principle, we could expect local residents to welcome such changes, and sometimes they do [7].

Correspondingly, there is also reason to expect that residents would value ecological goals and benefits of infill development, because public awareness of climate change and environmental problems is widespread.



Anyway, infill development may also have adverse effects if not well planned and the densification is too high [7][8][9]. Residents' opposition to infill have often been addressed to fear of adverse effects on their living-quality. Residents tend to be concerned about e.g. crowding, traffic overload, noise, safety, and about increased social problems. Decrease in privacy, loss of parking space, loss of open space, sunlight and views and especially green space cause worries or have been experienced as problems of infill [7] [8] [10].

Also in Finland, densification-oriented policy has been a stated goal of urban planning since 1970 and is currently an important strategic aim. Despite of these efforts, urban sprawl tends to continue [11]. Much of the potential land for infill in Finland is located in suburban areas that were built relatively loosely mainly in 1960-70's during the rapid urbanisation period. In these areas, a substantial proportion of land is owned by limited companies called apartment house companies, which is a typical legal arrangement of flat ownership in Finland. This means that the company is registered as the title owner instead of residents. Residents' own their apartments indirectly as shares of the company [12]. As shareholders, they are the ones making the decision about providing their land for infill. This form of flat and land ownership sets an important role for individuals. They are not only residents, but also landowners and shareholders. Thus, in Finnish context understanding the thinking of residents is emphasised and vital for the succes of infill projects.

This study analyses residents' attitudes towards infill development in their neighbourhood and aims to understand reasons for opposing or favourable attitudes. According to attitude theory, the formation of attitudes is based on subjective beliefs and evaluations about the attitude object [13][14]. Aiming to understand residents' attitudes, it is necessary to know what kind of positive and negative consequences residents *believe* that infill will have on their neighbourhood as well as how much they assign personal *value* to each of these consequences. Informed by expectancy-value model of attitudes [13][14], this study addresses both of these antecedents of attitudes, namely beliefs and evaluations. These theories postulate that attitudes are based on beliefs regarding only those consequences / product attributes, which are salient in persons mind; i.e. relevant and personally valuable for an individual. Consequently, to study attitudes towards infill, we should understand which qualities of residential environment are the most relevant for residents.

Methodology

Study areas and respondents

This study focuses on residents, who own their apartments in apartment house companies in Finnish suburbs. The sampling started by identifying suburbs, which have been built mainly during the years 1960 – 1989 in the capital area of Finland. Potential for infill (free permitted building volume) and existing plans for future infill activities in these areas were used as inclusion criteria. The data includes also a few locations where infill is in process. The 23 areas chosen for the study represent different types of suburbs in terms of prevalent building age, location and the planned placement and size of the future infill site. Postal questionnaires



were sent to 4 482 persons in January 2014 resulting in 1114 completed questionnaires. After removing residents who did not own their apartment the final sample size is 906.

Most of the respondents (82%) lived in 1-2 person households, and the share of families with children was 14.5%. Over half of the respondents (62.6%) were women, and the oldest person in the household was above 50 years old in 74% of cases. Nearly half of respondents (47.6%) had college or university level education (about 13 years of education).

Measures

Attitudes towards infill was measured by asking: “*Are you in favour or against infill development in your neighbourhood?*” Responses were given on 7-point scale (1 = “*I am against infill development*” and 7 = “*I am in favour of infill development*”). For further analyses, groups of opponents and supporters were formed. Respondents’ with attitude ratings 1 – 2 were classified as opponents and respondents with scores 6 – 7 were defined as supporters.

Prior to asking respondents’ opinions, they were provided with an introduction to infill development and its’ aims. Infill development was defined as development of new apartment houses within the existing city structure. The ecological, functional, social and economic goals of infill development were described with a few sentences. The introduction concluded with pointing out that obviously, these aims of infill development are not always realised and infill development may also have negative consequences especially from the point of view of local residents’.

A list of 23 statement pairs was designed to measure respondents’ beliefs in various potential effects of infill development. The creation of belief statements was informed by previous literature with the aim to cover aspects from: 1) concerns or benefits local residents associate with infill e.g. [3], 2) dimensions of perceived residential neighbourhood quality, such as social, functional, architectural, aesthetic and atmosphere, e.g. [15], dimensions of basic human needs for residential environment, such as contact with nature, aesthetic preference, recreation and play, social interaction-privacy, and community identity [16], and 3) the aims, and expected benefits of infill as understood in urban planning policy, e.g. [5][17].

To measure residents’ *beliefs (b)*, respondents were first asked to imagine that infill development will be carried out in their neighbourhood, regardless of the actual situation. They were then asked to rate, for each of the listed statement pair, to what extent they believe in that infill development would have these positive or negative consequences. Statements on the left hand side described negative expected consequences (such as “*the public transportation services in the area will get worse*”) and the statements on the right hand side described a correspondent positive change (such as “*the public transportation services in the area will improve*”). Answers were given on a nine-point scale, where the lower values (1-4) refer to expected negative consequences, 5 to “no change”, and the higher values (6-9) indicate belief in positive consequences.

To measure *evaluations* (e), the same subject issues were listed again in positive form (such as “*good public transportation*”) and the respondents were asked: “*How important it is for you that each of these issues will actualise in your own neighbourhood?*”. Answers were given on six-point scales ranging from 0 = not important to 4 = very important and finally to 5 = absolutely necessary.

Based on the attitude theories, e.g. [13], new BE ($b_i * e_i$) variables were formed by multiplying each *belief* (e.g. “*the public transportation services in the area will get worse – the public transportation services in the area will improve*”) and correspondent *evaluation* (e.g. “*the public transportation services in the area will improve*”) variables. In this way, both the strength of the belief and personal importance of that were considered. Prior to variable formation, the original belief scales (1-9) were recoded into scales ranging from -4 to +4. Thus the values of the resulting BE -variables range from -20 to +20.

Principal component analysis was performed on the entire set of 27 BE-variables in order to reduce the number of variables to analyse. Conceptual clarity as additional criteria, new aggregated variables were formed as means of several items loading on that dimension (Table 1).

Table 1. Aggregated and one-item variables used in the regression analyses. Note that the BE-variables are construed as products of evaluation and belief -variables ($b_i * e_i$).

Variable name	Description	Comprised as the mean of:	Cronbach Alpha	Mean
BE_UNIQUE_IDENTITY	Unique identity of the neighbourhood, pleasantness of the architecture, preservation of historical features and the extent to which residents can feel the area as their own.	BE2_architecture, BE3_unique, BE4_historic, BE5_feels own	.912	-2.8
BE_NATURE_PEACEFUL	The neighbourhood provides possibilities for relaxation, experiencing nature, is peaceful and has orderly, coherent appearance	BE16_relaxation, BE17_nature, BE22_coherent, BE25_peaceful	.894	-5.1
BE_TRAFFIC_CAR_P	Ease of car transport, traffic load and availability of parking lots	BE12_cartransport, BE14_trafficload, BE23_parking	.781	-4.1
BE_SERVICES_PUBICTR	Quality of local services and public transportation	BE9_services, BE11_public transport	.791	2.9
BE_RESID_REPUT	Types of residents, social disturbances and area reputation	BE6_welthier residents, BE7_area reputation, BE8_disturbances, BE15_immigrants	.833	-1.7
BE_RESCOUCE_SAVING	Natural resources will be saved. The city saves money.	BE20_citycost, BE21_nat_rescources	.773	-1.4
BE10_social life (one item)	Sense of community and social interaction	BE10_social life	-	-0.2
BE19_safety (one item)	Safety of the neighbourhood	BE19_safety	-	-3.7



Results

Attitudes and beliefs concerning infill development

Approximately 32% opposed infill clearly and 44% to some extent, 19% was in between and 35% were at least to some extent in favour of infill development. General attitude towards infill development was not significantly related to respondents' gender, level of education, or attitude towards sustainable development. Small, but statistically significant correlations were found with age ($r=-.10^{**}$), the level of equalised income ($r=-.07^*$) and years of living in the neighbourhood ($-.09^{**}$) suggesting that older respondents, those who have lived long in the area and those with higher education levels tend to have more negative attitudes towards infill. The mean attitudes towards infill did not significantly differ between those who had and those who did not have *previous experience* with infill.

Beliefs about consequences of infill

Regarding the anticipated consequences of infill, most beliefs were on the negative side. *Improvement of public transportation* (B11) and *improvement of services* (B9) were the only two beliefs that were positive on average. The expected influences on *neighbourhood reputation* (B7) and on the *whether wealthier people will move into the area* (B6) were at neutral level, in average. On the other hand, most negative consequences were expected on "*possibilities for experiencing nature in the neighbourhood*" (B17), "*peace and quiet in the neighbourhood*" (B25) and the on *amount of traffic, and traffic jams*, which were expected to increase (B14) (Figure).

All the measured beliefs had significant positive correlations with attitude. In Figure 1., this can be seen as differences between the opponents and supporters, which were all statistically significant (anova). The supporters tended to believe more in any positive consequences than the opponents.

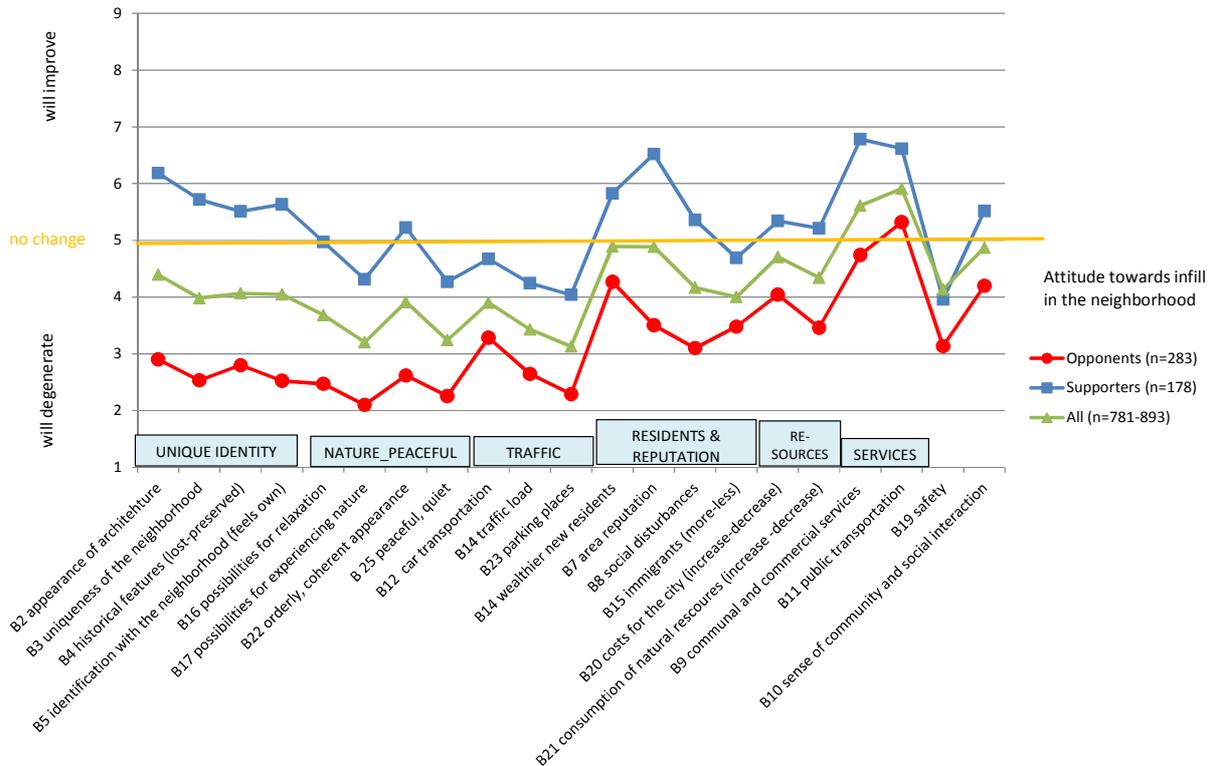


Figure 1. A sample of respondents’ beliefs regarding expected consequences of infill development in the neighbourhood. Means for opponents (rating 1-2), supporters (rating 6-7) and for all respondents. The blue rectangles refer to aggregated BE-variables. The means of all these variables significantly differed between the opponents and supporters (anova).

Attitudes explained

In order to find out whether some of the beliefs are better predictors of the attitudes than others, linear regression analyses were performed using the BE variables (listed in Table 1.) as independent variables and attitude towards infill as the dependent variable. Because of incoherent beta-coefficients (beta coefficients were negative while correlations were positive), three variables were left out from the final analysis: BE_TRAFFIC_CAR_P; BE_RESCOURSE_SAVING, BE10 social life. In the final model, 47% of the variability in attitudes towards infill development was predicted by knowing these five independent variables. Three of them significantly contributed to prediction of attitudes (Table 2.)

Table 2. The results of the final regression model $R^2 = .47$; Adjusted $R^2 = .47$; ($F(4, 374.9) = 190.4, p < 0.000$)

	Standardised beta	Sig.
BE_UNIQUE_IDENTITY	.39	.000
BE_NATUR_PEACEFUL	.23	.000
BE_SERVICES_PUBLICT	.12	.000
BE_RESID_REPU	.04	.311
BE19_safety	.02	.691

The results suggest that some of the respondents' beliefs are more strongly related to their attitudes towards infill development, than others. Anticipated effects on the unique identity of the neighbourhood and for the possibilities of experiencing peace and nature seem to be the most important predictors (or antecedents) of attitude, followed with services and public transportation. This means that if the respondent, for example, beliefs infill to harm the unique identity of the neighbourhood and also values it, he / she is more likely to oppose infill development. Further, a person is more likely to have positive attitudes towards infill, if he/she values peace, nature and services and does not expect infill development to weaken these amenities.

On the other hand, respondents' expectations regarding the social life or safety in the neighbourhood had less relevance for their attitudes towards infill. The same applies for expected influences on traffic and on resource saving.

Discussion

This study aimed to understand suburb residents' initial attitudes towards the idea of infill development in their neighbourhood.

As could be expected based on previous studies, most respondents had resistant attitudes towards the idea of infill in their neighbourhood. In line with their prevalently negative attitudes, the respondents believed more in the negative than in the positive consequences of infill development. Negative consequences rated as most likely, in average, related to: possibilities for car parking, possibilities for experiencing nature, peace and quiet in the area, traffic congestion, distressing building density, and possibilities for relaxation to name a few. Only a few of the listed consequences of infill were believed to be on the positive side, in average. These were improvements in public transportation services, in other services and recreation activities, more diverse social structure, and improved area reputation.

All the respondents' concerns are familiar from previous studies, e.g. [3][10]. Somewhat on contrary to previous studies, e.g. [3][18] *social disturbances* and *safety* were not among the greatest concerns among our respondents. These results assumingly reflect the nature of Finnish suburban areas which are relatively low in density and loose structure [19].



This study, however, differs from the most previous ones in that we did not only list the concerns local residents have, but analysed which of the issues are most valued by the residents and which of them can best explain the attitudes towards infill. The results suggest that one of the key factors explaining residents' resistance to infill relate to their beliefs and values concerning the unique character and identity of their neighbourhood. They believed that it will not remain the same after infill and they would feel less at home there than previously. Home environment has important psychological meanings to individuals [20]. Thus, one reason for the relative importance of this variable may be residents' experience of threat against their psychological security and identity.

The second most important predictor of attitude related to respondents' beliefs and values regarding what happens to nature, peace and their possibilities for relaxation after infill. The result is not surprising given that peace and closeness to nature have been repeatedly been found as highly valued by Finnish residents regardless of their demographic background [21], and contact with nature has be regarded as a universal need from urban landscape [16].

Compared to the policy goals of infill development, residents' notions of the benefits of infill were quite different. Only few issues coincide. Based on this study, many of the aims of infill, such as vibrant neighbourhood, social diversity or better social relations, or saving financial resources, seem not to be able to motivate residents' to accept infill construction. Environmental sustainability is a further example. In principle, the Finns do value environmental friendliness of their living environment [22]. Still, most respondents did not believe infill to bring about savings in natural resources, neither did this belief influence attitudes towards infill.

This study suggest that, at least in Finnish suburban areas, residents' concerns about any negative changes in the neigbouhood and especially those related to uniqueness of the area and nature amenities should be addressed in infill processes. Improved services and public transportation and to some extent also area reputation may be ways to encourage infill acceptance.

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Tactical Urbanism: A Method of Community Empowerment in Cairo Neighborhoods (Best Papers SB13 Cairo)

Speaker:

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Abstract: *This paper follows the principles of Tactical Urbanism Cairo, Egypt. It presents an approach to solve problems of vendors in Cairo. The core issue revolving around: "make a relative balance in the application of the principles of Tactical Urbanism taking into account the achievement of the urban design dimensions especially the behavioral one to accommodate the change and robustness in human needs and rights." The research structure depends on three objectives. First, it interprets the concepts of Tactical Urbanism and Place theory. Second, it analyses the current scene in selected case study. Third, the paper designs an approach to open a wide dispensary to solve the vending problem. The contribution of the approach is to deal with the general problem in the Egyptian context caused by vendors. Finally, the paper tests the principles and the approach of tactical urbanism in informal sectors in the Egyptian urban fabric.*

Keywords: Tactical urbanism, street vendors, park(ing) day, Cairo, informal activities

Introduction

Tactical Urbanism is a common term used through community building and rehabilitation. Several approaches deal with this trend in the developing countries as a tool to raise up the urban environment that suffer from selfish vandalism. It can reflect a powerful form of community-supportive activism. Today, overcrowding and informality is a remarkable phenomenon in Egyptian cities, but is most evident in Cairo. On the other side, that informal sector in the capital holds several unemployed citizen. Being a capital holding that types of informality may affect the livability even for inhabitant or for visitors of Cairo. The objective is to follow the approach of Tactical Urbanism to get the results of typically a series of small-scale interventions that alter the public realm. In addition, it makes it advocate more user-friendly for the public.

The paper presents a method to apply the principles of Tactical Urbanism on an Egyptian neighborhood unit. This method tries to solve the problem of existence of unemployed in Cairo. The research structure depends on five objectives. First, it interprets the concepts of Tactical Urbanism and its potentialities in the Egyptian context. Second, it discusses the trend of city repair," or "do-it-yourself "DIY" Urbanism to find out the philosophical approach. Third, analysis the current scene in selected case study. Fourth, the paper designs an approach to deal with the vending common problem in the Egyptian context. Finally, the



paper recommends a research project to test the principles and the approach of tactical urbanism in informal sectors in the Egyptian urban fabric.

The originality is represented in raising the issue of the research to attach one of Egyptian problems; the informal sector and unemployed people. The core issue revolving around: "make a relative balance in the use of the principles of Tactical Urbanism in Egypt neighborhood taking into account the achievement of the urban design dimensions especially the behavioral one to accommodate the development and robustness in human needs and rights." The contribution and outcomes lay in to begin the practical application of the informal sector in Egypt, bearing in mind that its scope is limited to the applied urban design projects to upgrading process in major urban cities.

Literature Review: A Movement and Theory

"In the twenty-first century, cities worldwide must respond to a growing and diverse population, ever-shifting economic conditions, new technologies, and a changing climate. Short-term, community-based projects—from pop-up parks to open streets initiatives—have become a powerful and adaptable new tool of urban activists, planners, and policy-makers seeking to drive lasting improvements in their cities and beyond. These quick, often low-cost, and creative projects are the essence of the Tactical Urbanism movement. Whether creating vibrant plazas seemingly overnight or re-imagining parking spaces as neighborhood gathering places, they offer a way to gain public and government support for investing in permanent projects, inspiring residents and civic leaders to experience and shape urban spaces in a new way" (Lydon & Garcia, [Tactical Urbanism, 2014](#))

Tactical urbanism is trend/movement come to the field of "City Repair" and "Do It Yourself Urbanism (DIY)". It aims to enhance the urban life experience through incremental action plans of improvements (Courage, 2013) (Figure 1). It is often small-scale, temporary, low cost, quick to install and dismantle, informal, spontaneous, participatory and driven by community issues, and often initiated by emerging architects, artists and creative urbanists working outside of professional boundaries (Shackelford, 2014). One of the most efficient axes in tactical urbanism is Park(ing) Day and Street Vending (Figure 2). These two phenomena are about making the places for people to draw attention towards particular local issues of livability, in a way far from crowded visual context. This urban intervention is differed from conventional activists' concepts in favor of fun activities (Coombs, 2012). The first official Park(ing) Day was in San Francisco, 2006 to draw attention to the lake of green space in downtown. Addition, tactical urbanism moves in a parallel way to create places for vendors to do business in outdoor places.



Figure 1: the five characteristic elements of tactical approaches, source: the author based on documents from (Lydon & Garcia, 2014), (Shackelford, 2014)



Figure 2: the principles of tactical urbanism, source: author

In return to the main crux of urban design to create livable places (Carmona & Tiesdell, 2007); (Eisinger & Seifert, 2012; Madanipour, 2010), street vending in Egypt participates in making sense of place. “the role of the urban designer is not merely to manipulate form to make space but to create a place through a synthesis of components of the total environment, including the social” (Trancik, 1986, p. 114). The place theory tries to understand the cultural aspect and human characteristics of the physical places (Norberg-Schulz, 1979). Trancik (1986) abstract the meanings to differentiate between urban spaces and places in case the designer involve the cultural contents. To design for a prosperity of both the physical and public life, experts should explore the local history, the feeling and the needs of the populace, the traditional lifestyle, and the reality of political and economic realities (Hertzberger, 1980). Looking at the city in parts, the place theory can be recognized in the term of three main axes: good city form (Lynch, 1984), sequential movement (Cullen, 1971), and the mutual impact of every physical and social component (Appleyard, 1982); (Jacobs, 1995). Cullen (1971) describes the feeling on users while they are moving in the city at the eye level. Lynch (1984) adds to Cullen’s description that the effective/ responsive form can analysed in term of legibility, structure, identity, and imaginability. Appleyard (1982) analysis the social complicit os street space in a way he assesses the impact of traffic on outdoor life. In this way, people usually modify their life. Thus, if the urban designer puts in consideration people’s way of modification and adaption the chaos becomes around.

In conclusion, the current research reviews a movement, and theory of urban spatial design: tactical urbanism, and place theory. These set of theoretical background has a wide contribution to one of the most common problem in Cairo; the street vendors. The potentially disruptive problem, in Egypt, is that the designer developers and decision makers are obsessed with designing phase to develop the context regardless to the whole urban environment. The key, therefore, is put in spot this theoretical base as contribution to vending problem in Egypt.



Street Vendors in Cairo: a Hidden Community Empowerment within Informal Activities

Street vendors are various in term of scale, types of goods, remuneration, location, and mobility (Figure 3). The term also refers to ‘street trader’ and ‘hawker’ (International Labour Office, 2013, p. 2); (Kusakabe, 2006). Street vendors may move depending on events in the city, the weather, customers’ location, or the time of day (Bromley, 2000). In Egypt, they offer an abundant part of the informal earnings income; they are responsible for 25% to 60% of GDP (Gross Domestic Product) according to some estimates (Viney, 2012). Once the unemployment is high (over12% at the end of 2011), and the bribery cases to initiate towards an obstacle, illegal course, trading on the street is often the only available act. Vendors that are not universally welcomed have increased, in part, owing to diminished harassment from authorities, who have turned their focus elsewhere (Cross, 2000, p. 41); (Williams & Gurtoo, 2012). Conventionally, street entrepreneurs were either seen as a residue from a pre-modern era that is gradually disappearing or endeavor into which marginalized populations are driven out of necessity in the absence of alternative ways of securing a livelihood.

Table 1: Classifications of vendors in Cairo, source: author’s observation of street vendors and (United Nations Human Settlements Programme (UN-Habitat), 2013)

Vendors’ Locations	Types of Vendors				Licensed	Period (hours)										Remarks
	Food	General	Amendment	Veteran		6am	10am	12pm	2pm	4 pm.	6pm.	8pm	10pm	12am		
12Metro Station		•	•	•	no											Food vendors also provide drinks and tea for bus drivers which called ‘farsha’. The time that vendors spend within in may be different from a site to another Based on the context.
Bus Stations	•	•			no											
Bus Stop		•	•		no											
Public Instruction	•	•	•	•	no											
Shopping paths		•	•	•	no											
Shopping malls		•	•	•	yes											
Crossing street (nods)			•		no											
Under bridges			•	•	no											
Inside public transportation				•	no											
Freeways exists	•			•	no											

Content Analysis of the Contestation: Vendors’s Attitude vs. Inhabitants’

Universally, literature on street vending can be categorised into four groups illustrated in (Figure 4), (Kusakabe, 2006). This research focuses on the third and fourth set because they are near to the concept of tactical urbanism. The short term action in the relationship between the vendors and a pubic space makes a long-term change in that relationship. The same can be found in the fourth set of literatures that have a long change on the quality of urban configuration. In addition, there are two obvious notes in street vending, in Cairo. The first, most policy, takes place in Cairo (Babb, 1989); (Cluster, 2013); (El-Kouny, 2012); (Elmaghrabi, 2014); (Mansour, 2011); (Nagati & Stryker, 2013) focus on the second and third

set of literatures. The second, from reviewing (Figure 3), all street vending in Cairo are unlicensed except kiosks with light construction that build in street platform.

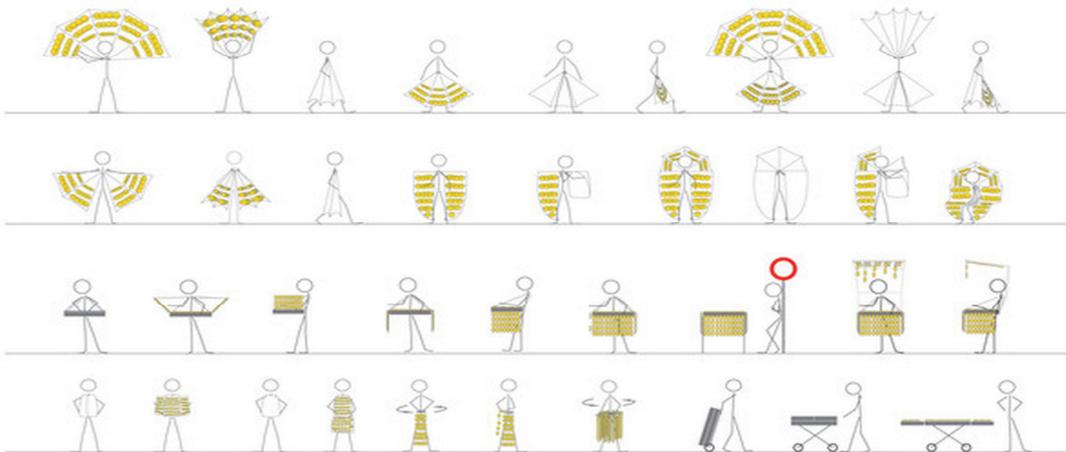
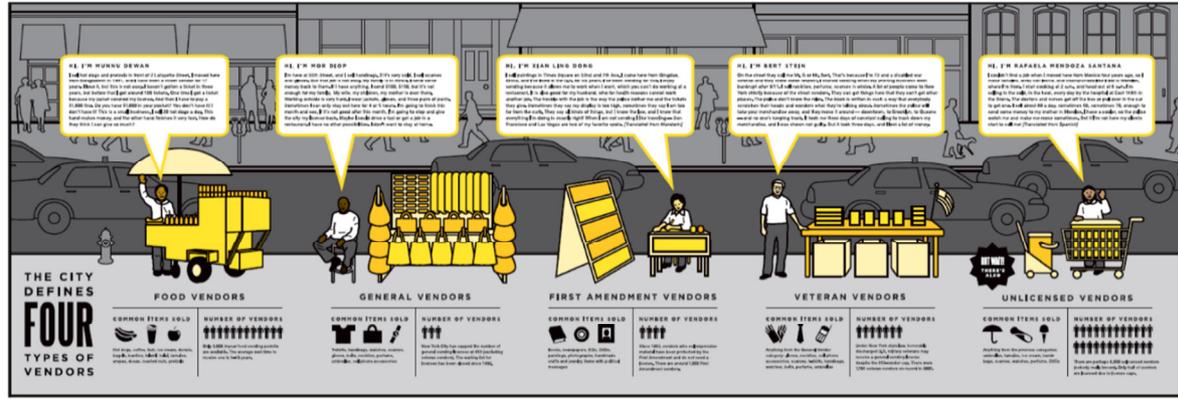


Figure 3: (top) Types of stable street vendors, source: (Lydon & Garcia, *Tactical Urbanism*, 2014); (Lydon, Bartman, Dwoudstra, & Khawarзад, 2010, p. 14). (down) types of mobile vendors, source: (Mansour, 2011)

To find out the characteristic of the Egyptian vendors' problems, the research chooses two approaches; content analysis and interview. The content analysis is based on the literature presses on the online journal during the last four years (El-Kouny, 2012); (Cluster, 2013); (Elmaghrabi, 2014). The interviewers' sample was chosen through some vendors and inhabitants inside the case study (ELShafie, 2013) (Figure 7). Obstruction caused by vendors is a significant obstacle to local citizen and passing-by traffic. According to the 2010 World Bank Cairo Traffic Congestion Study, congestion costs the city \$13-14 billion LE (\$2.1-2.3 billion USD) annually in wasted fuel and time. Action to support traffic flow more efficiently, the government, is endeavoring relocation of vendors to side streets or to resettle in surrounded marketplaces. This action may not prove successful. Vendors unavoidably be attracted to the busiest and most profitable paths. In whatever place, some would be ready to pay for the right to do his informal business. On the other side, vendors are not welcomed in Egypt by inhabitants where they make a disturbance to their privacy although they buy, sometimes things from them (El-Kouny, 2012). They hold a feeling of marginality and

exclusion of the society. Several action plans were taken to move in another place; 6th of October city which located many mile fares from Cairo. The vendors’ comments to the action represented in (Figure 4).

Table 2: Vendors’ opinion versus the users’, source: author

Vendors’ Opinions	Users’ Opinions
We belong to the place; we are from here.	They are not like us; they make much noise
We cannot afford to leave Cairo	They have to move in a way this area
Consumer demand is for affordable goods and provide it to him/her easily, and cheaper	Cheaper goods are available for poor people
	States should provide open market outside Cairo for vendors
We do not look for trouble	
Most of us are responsible of a family, and we have no fixed income	

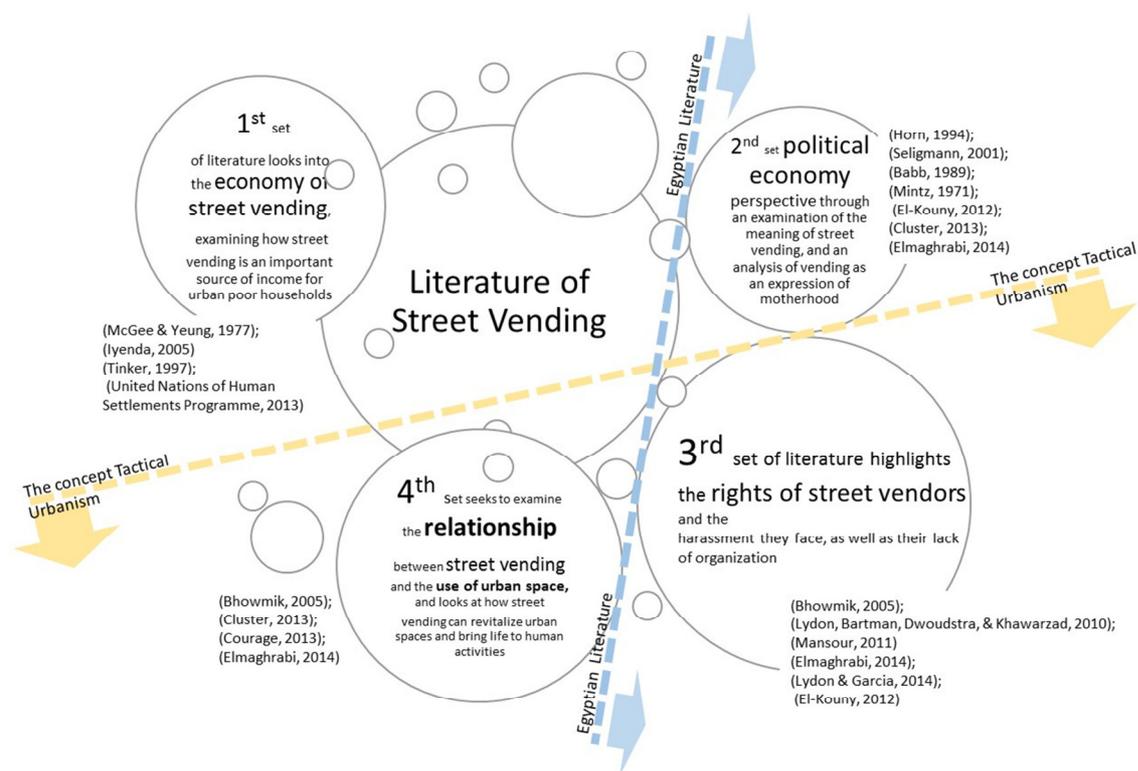


Figure 4: The four set of literatures of street vending, source: author

Lydon and Garcia (2014) mention that whatever the given the limited street space, a suitable arrangement can provide more rooms for efficient usage of it. Commercial activities are genuine and vital use of the street, as is transportation. Vendors should be permitted to sell in well-trafficked areas that are visible and accessible to customers, as is being prepared in some areas. Public transport should be given priority, perhaps by designating exclusive bus lanes, although they depend on traffic requirement unless there is a physical barrier. Provide parking area where vendors are located near the parking exits facilitates to keep free-flowing situations (again, enforcement is key). Considering vendors as unwelcome citizens earning money in illegal in any site is critical issues. This may cause a social negative impact once

they gathered. For this reason, an article (Mansour, 2011) present an initiation as solution (for vendors with regardless of the others’ protestations (Figure 5). Mansour (2011) gives a suitcase addressed “Ali Baba Box” to help the vendor display his goods in a foldable way.

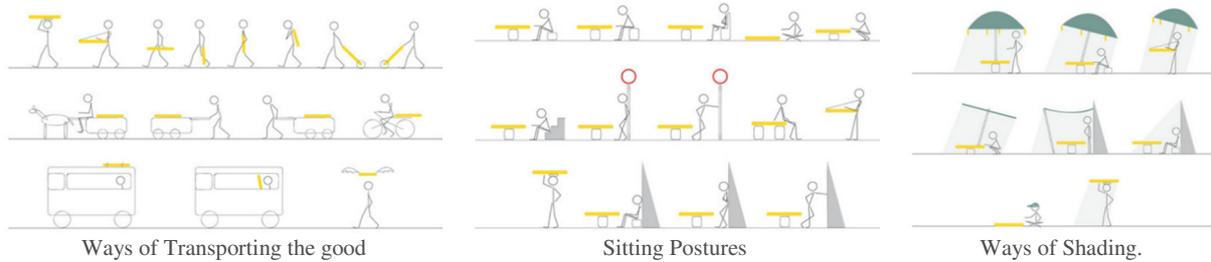


Figure 5: attitude of mobile vendors, source: (Mansour, 2011)

The Analytical Study: Existing Situation raised from observation and interviews

This research was conducted on a path in Cairo (Figure 6), where the author resides. The author’s residency there provides clear discovery of the district’s context over seven years. Generally, the path passes through district that serves various functions: residential, educational, administrative, and for cemeteries. In addition, the site is surrounded by vending uses to the south and southwest (Figure 7). The site’s boundaries were set within walking distance (300 m). Additionally, the site holds attraction poles for vendors: bus station, exits of underground metro, educational public building, and administrative uses. Some photos were recently taken to depict the chaotic elements of built environment (Figure 6).

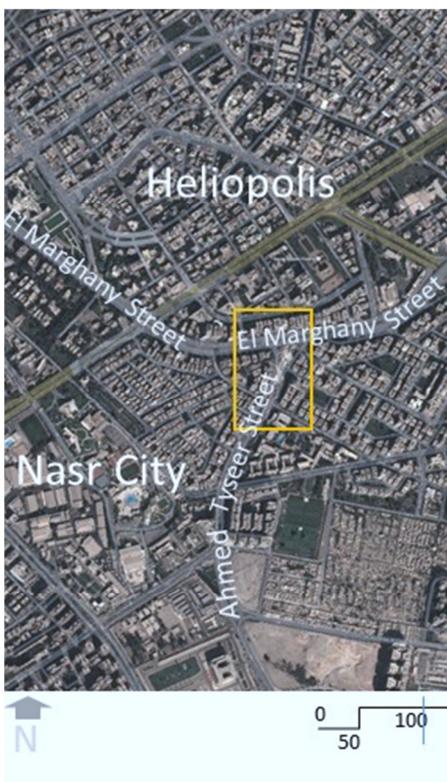


Figure 6: case study location, source: author based on Google Earth



Figure 7: Site analysis and the existence of vendors, source: author



The outcomes of the site analysis phase can be regarded in the followings (Figure 7):

- The path span provides as an opportunity for both the street user and street vendors to participate a range of activities. The width is varied between 200m at its entrance and 75 m at end.
- There is a social collapse between the vendors and inhabitants. Parking cars compete with vendors that may cause frequented quarrel.
- There is no rule or law adjusts the relationship between the vendors and inhabitants and even between vendors.
- Umbrella or shading tools are used by vendors to create territorial demands. These treatment in all case is poor in urban aesthetics.
- Vending in the sidewalk prevents a flow for pedestrian. Sidewalk as a margin of demonstration between private and public domains encroached upon and often rendered impossible for the pedestrian.

Short Term Action towards Long Term Change

In this level, the research proposed a four axial solution (Figure 8): people, time, place, and laws. Some few concepts can be discussed to develop the proposed methods the others is listed in the last mentioned figure. Dealing with problems caused by vendor should cover multidisciplinary system established to cover the context of the city which is different from others. The new development project should have a maxim benefit of the day/holiday/festive/anniversaries time. This to manage the time spent equally between users and vendors. These projects lay attention to people whether they are vendors or inhabitants. For this inhabitants considering the behavior setting of both vendors and inhabitants, must be put on a priority. On the other side, getting the over the environmental impact on the context raise the urban aesthetics toward physical prosperity. The physical tactical action that can be taken place in the context should consider the lost space and get the maximum benefit of place and design for good accessibility. A review and guided process should establish for every context. The main task that it focused on, for example, assist and review in vending and display, vending design Process.

Conclusion

This paper tried to find out the relationship between the principles of tactical urbanism with one of the most common problem in Cairo, Egypt; vendors. This was under a certain hypothesis. The hypothesis is true if taken into account the following notes. First, the public participation can play a role in motivating the tactical urbanism principles, towards a real application. For examples, although the tactical urbanism called for park(ing) day as a raising of community empowerment, some communities are against the idea. Second, the action plans of tactical urbanism should respect the cultural context of the certain context which conserve the crux of the place theory. Third, the mutual impact between the four proposed action needs to be tested through a digital model.

The current work is based on a research justification to follow the analytical approaches. This approach focused on the content analysis and interviews for both vendors and residents in the case study. In conclusion, the crux of the current paper is to give a contemporary action plans guided by the theoretical base towards the problems of vendors in Cairo. It extends to propose an analytical study to find out relationship between vendors and built environment through an approach of finding lost space.

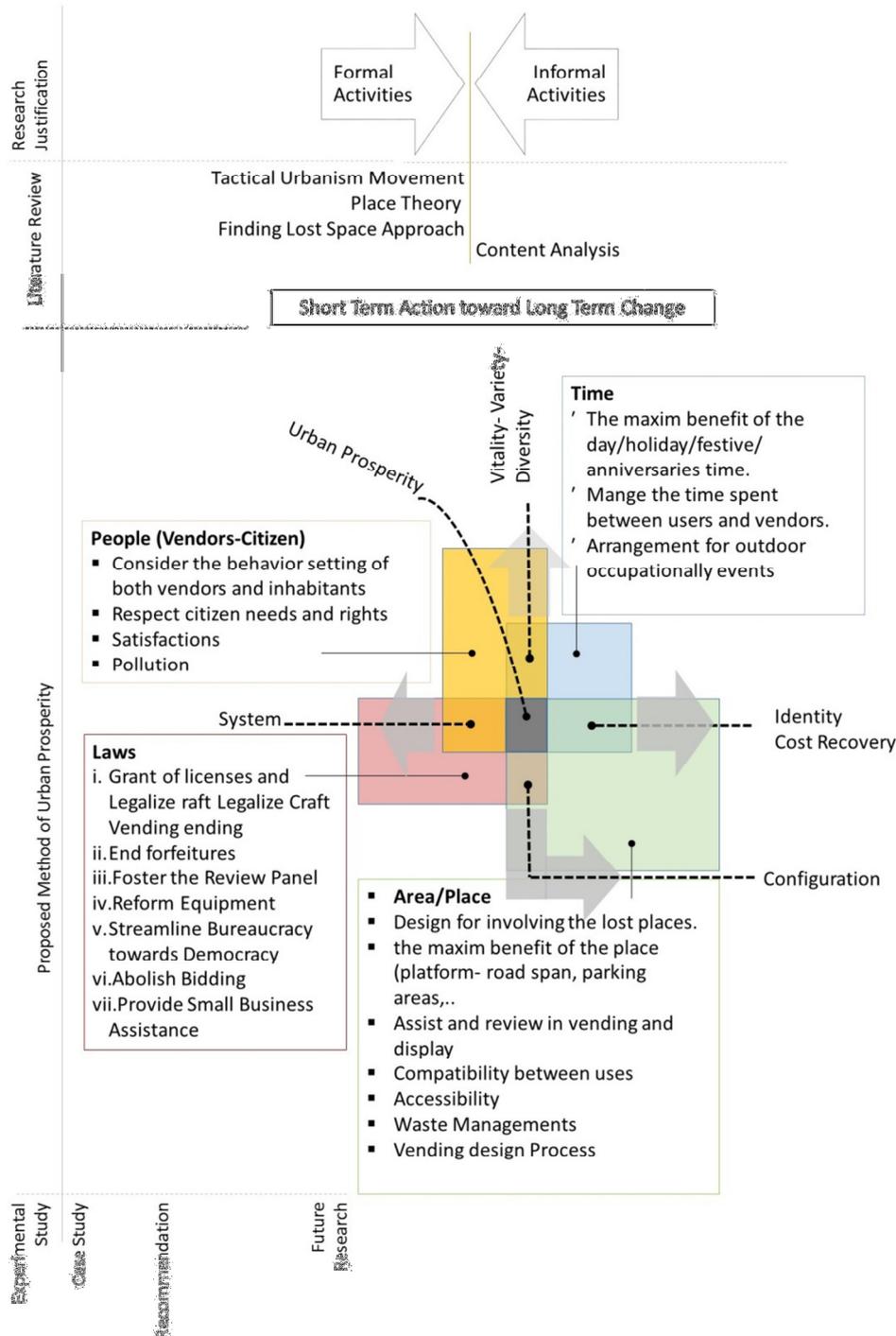


Figure 8: the proposed four axial solution of the vending problems, source: author



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Social impacts of citizen participation in service development. A case study from a Finnish urban neighbourhood

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Abstract: *This study aims at further strengthen the statements about a positive correlation between citizen participation and well-being of the neighbourhood. Service co-creation, social impacts and the sense of community of a neighbourhood are key focus areas of the study. By examining our case neighbourhood – a Finnish urban suburb from the 1970s – we found evidence to claim that it can be highly important to, by different means, support services which increase social activities and interactions, and thereby decrease social risks. The other strong observation made is that, although challenging, collaboration between different local actors can be highly valuable and it can create synergy solutions. With the support of our case study we argue that three key elements are necessary for the co-operation and service co-creation to evolve: first, availability of facilities and open places where people can meet and change ideas, second, collaboration and informal meetings and third, a key person who is eager to bring individuals and groups together, implement actions and take risks.*

Keywords, Social impacts, neighbourhood well-being, service design, citizen participation, value creation, sense of community

Introduction

Service science is an interdisciplinary field that focuses on fundamental science, models, theories and applications to drive service innovation, competition and well-being through co-creation of value. As Ostrom et al. [1] present, service innovation creates value for customers, employees, business owners, alliance partners and communities through improved service offerings, improved service processes and service business models. Value co-creation has been a basic idea of many researchers in the field [2][3]. Vargo & Lusch [3] highlight in their theory about Service-dominant logic (SDL) the importance of co-creation by stating that a customer is always a co-creator of value and by highlighting the importance of value networks (service ecosystems). Experience and thereby perceived value is created in a service process.

This study examines the services at a neighbourhood level. The importance of services for a neighbourhood well-being has been proven by several sustainability assessment systems. For example in the ISO 21929 (Sustainability in building construction) standard [4] one of the 14 indicators is availability of services and it is measured as distance to public and personal modes of transportation, green and open areas and to user-relevant basic services. Also the eco-efficiency assessment tool for city planning, HEKO, encompasses five entities, one of which is transportation and services, including the indicator: distance to basic services (day



care, primary school, store) and broader services (library, postal office, health centre, secondary school and more diverse commercial services) [5].

The premises of our study are also related to *shared value* theory presented by Porter and Kramer [6], which suggests that companies and society should co-operate in order to create not only economic value for the company but also social benefits for the citizens. The principle of shared value creation goes beyond the corporate social responsibility (CSR) thinking, and it discards the traditional division between the responsibilities of businesses, governments and the civil society. According to the shared value theory it does not matter, from society's perspective, what types of organisations created the value. More important is that benefits are delivered by those organisations – or combinations of organisations – that are best positioned to achieve the most impact for the least cost.

Citizen participation and social impacts

The underlying assumption of this study is that in order to develop a sustainable, wealthy and valuable neighbourhood, new collaborative means and services are required. Several studies have proven the importance of citizen participation, level of interactions and the sense of community, describing them as contributors for human wellbeing and for a vital neighbourhood [7][8]. The ISO 21929 standard [4] has an indicator about participation, describing the level of stakeholder involvement which does supposedly contribute to social equity. Also the TISSUE-project highlights the importance of indicators related to citizen participation; TISSUE presents an indicator for citizen participation in planning and the satisfaction with the state of the urban environment but in addition to this, another indicator for measuring how local firms and organisations endorse their responsibility towards the environment and the local community [9].

Urban planning is often criticised because it does not sufficiently enable the participation of citizens and different actors for whom the suburbs are meant for [10]. According to a survey carried out by Halme et al. [11] the majority of the respondents shared the opinion that the residents should have a possibility to participate in the service development of the neighbourhood. Heinonen and Ruotsalainen [12] present that future suburbs should include 1) experimental and meaningful environment and life, 2) Local democracy, activities from the grass root level upwards and 3) hybrid spaces to connect new ways of utilisation and different activities of the neighbourhood. Needs to improve the sustainability of Finnish neighbourhoods is a current and increasingly important question, and there exists a growing level of knowledge and technologies for carrying out the improvements [13]. During recent infill development projects (Peltosaari and Tammela) a conclusion is that it is important to survey social dynamics simultaneously with examining the building stock and infill potential [14]. In greenfield urban development areas participation of inhabitants into planning is low due to small amount of inhabitants in the beginning. In the old neighbourhoods all residents are potential participants in planning and giving feedback. Different means and participating methods are therefore necessary in order to involve all inhabitant groups to service development.



Social impacts of sustainable built environment constitute the main area we are focusing on. For example the Finnish Ministry of Justice [15] defines social and health impacts as factors influencing a human, a group of people, a community or a society. The impacts might influence mental or physical health, well-being or living conditions of people, or the way how well-being is divided between people (for example between different socio-economic groups). According to the ISO 21929 standard [4] buildings and construction sector is an important industry which has remarkable economic and environmental impacts but it also affects social conditions significantly. Sustainable buildings and infrastructure can be seen as a platform for services and living. According to Tapaninen et al. [16] the environment is related to the sense of community and to well-being as it is the scene for human activities. A good environment is created by social interaction of planning, development and doing. By creating good environments it is possible to ease the belonging to a group and develop sense of community.

Social impacts and well-being is also linked to the concept of social capital which is, according to many studies, associated with civic engagement [17]. For example the study by Mellor et al. [18] examining personal and neighbourhood well-being indicates a strong relationship between volunteering and personal and neighbourhood well-being. Several efforts have been made in order to increase the well-being and the sense of community of neighbourhoods but the projects cannot take off without engaged people. Therefore socio-cultural inspiration has a strong role in social growth and community development, as it motivates people to commit themselves to different activities [19].

Research questions

The main research questions that this study aims at answering are: What are the new approaches or roles of stakeholders in service development? How can the user value be created in such a way that it will have strong social impacts and it can contribute to the social well-being of the neighbourhood? Which measures or boundary objects can be implemented for supporting collaborative service development? And what is the level of capability of local actors to contribute to co-creation of value?

The expected outcome is to find support for further strengthening the statement about positive social impact of citizen participation in service development, also enabling value creation for the whole neighbourhood. With the support of our case study we aim at giving suggestions on which elements are necessary for the service co-creation ecosystem. We also seek new approaches to present problems in development of existing urban district by means of city planning added by means of service ecosystem development.

Methodology

An urban suburb from 1970s in the capital region of Finland was chosen as the case study. The aim of the case study was two-fold: The first objective was to identify service-related preferences, demands and thoughts by the residents and different actors of the neighbourhood. Second, a method for incorporating citizens into service planning and designing was tested.



Main research methods were a survey and interviews, for identifying the resident perceptions, and a living lab for testing the user engagement method.

The Case study – the urban suburb of Hakunila

Hakunila is an urban suburb of 11 000 residents, located in the city of Vantaa, in the capital region of Finland, and it is part of the greater Hakunila, with close to 30 000 inhabitants. Hakunila can be characterised as a typical Finnish suburb from the 1970s. There are approximately 300 suburbs in Finland – half of which were built in the 1970s – accommodating about one million people. Since the 1990s there has been a growing demand for renovation of the buildings and the built environment in the suburbs. Also the social problems of the suburbs became a matter of concern in the 1990s [20].

Some of the numbers characterising Hakunila do not indicate particularly high social and economic performance of the neighbourhood: Hakunila has a considerably high unemployment rate (14,8 %; 9,1% in Vantaa) and a large non-Finnish speaking population (18,8%; 9,1% in Vantaa) and half of the apartments in the neighbourhood are rented flats [21]. Main services in the neighbourhood consist of two supermarkets, a kiosk, a library, a health centre, a pharmacy, a church, a hair dresser, a few specialized shops, a video rental, a flea market and several pizzerias and pubs, most of which are located at the commercial centre built in the 1970s and 1980s. The distance to the largest centre of Vantaa is about 5 km and the distance to the Helsinki city centre 17 km. Public transportation is good with dense bus connections to Helsinki and other parts of Vantaa.

Hakunila is the third largest population centre in Vantaa and as a result of strong construction boom there are several flat roof apartment buildings from the 1970s which dominate the scenery in the centre. However, Hakunila also has a large amount of cultural-historically important landscape with old mansions and diverse nature as well as great terrain for sports and other outdoor activities. Built environment is considered as scenery for life and well-being. Services that are targeted to maintain and upgrade its qualities are part of the observation focus of the study.

Interviews and questionnaire

To identify perceptions by the residents and actors of Hakunila, an interview and a questionnaire was carried out. The interview was a semi-structured interview with strict questions, but including also unplanned questions and conversation, depending on the interviewed person. The questions were related to describing the suburb with suitable adjectives, importance of different services in the suburb, good and bad things of the suburb, future scenarios for the suburb and news which would improve the image of the suburb. The questions were multiple choice questions, with the possibility for the respondent to add their own comments and descriptions with free words in many questions. The interviewed persons were people who have an important or active role in Hakunila (e.g. head of the school, CEO of the maintenance service company, members of the city council, head of the library) and



have a special understanding about the problems, the current situation and the development of the suburb. Altogether 10 interviews were carried out between spring and autumn of 2012.

The questionnaire was launched in internet and answers were also collected on a paper form. The questions were similar to the questions used in the interviews but with less possibilities to write the answers in own words. The target group for the questionnaire was all residents of Hakunila and the questionnaire was disseminated through different channels, e.g. emailing lists, paper advertisements and by spreading information at the commercial centre. Replies are still being collected at the time of writing this paper but preliminary results can already be discovered.

Workshops and living lab

Another major method of the research was organising two participative workshops for residents and actors of Hakunila. The first one was organised in September, on the Hakunila-day, when different people were gathered at the square of the commercial centre of Hakunila. The workshop was arranged at the youth centre, located at the commercial centre, and people were encouraged to share their ideas about what - especially service-related - improvements could be made in order to upgrade the well-being and the image of the neighbourhood. People were encouraged to take one step further and also give suggestions on how to bring the ideas to a practical level. The workshop served as a living lab in which the interest and potential of the citizen participation was tested. Facilitation method used was based on supportive and responsive leadership styles during the face to face dialogue sessions and participants were helped by open ended question to describe their ideas and opinions.

The second workshop was organised in December at Hakunila church. Again, different actors of the neighbourhood were encouraged to participate and discuss about methods to improve the well-being of people in the suburb. The main objective was to provide the different actors an opportunity to find ways to collaborate and to change ideas and information and to observe how the citizen collaboration and co-creation would start to evolve.

Results

This paper presents the preliminary results of the case study. The interviews and the questionnaire presented interesting insight into the Hakunila residents' and actors' thoughts about their surrounding region. Similarities among the respondents could be identified very easily as some issues were highlighted far more than others. According to the interviews and the questionnaire the residents of Hakunila mostly appreciate their neighbourhood because of the existence of nature, cosiness and the high sense of community. The most important services of the suburb are the supermarkets, the library, health centre and the pharmacy. Residents would like to have more social activities, better commercial services and meeting places and less social problems and disorders in the neighbourhood. The respondents were highly unanimous that the bad image of the suburb is a highly important issue which should be improved. The perception of the future looks considerably good as most of the respondents



agreed on the statement that “Hakunila will be a vivid, cosy, multi-cultural suburb, attracting different people with its extensive services and diverse activities”. However, differences between the interviewed people and people responding to the questionnaire can be pointed out here as interviewed persons, who are having an active role in the neighbourhood, gave more optimistic responds compared to the people responding to the survey.

These results are fairly identical to a study carried out by Halme et al. [11] according to which the residents of the examined suburbs found the supermarket, post office and pharmacy as the most necessary services. Even if the natural environment was not considered as a service as such in Halme’s research, the residents did think that the nature and spaciousness improved the attractiveness of the living environment. An interesting finding was that almost all respondents thought that Hakunila is a better neighbourhood than its reputation implies. Another rather surprising finding was that people in the region are considerably active and there are several associations and clubs in the neighbourhood. This suggests that the residents of Hakunila share a considerably high sense of community which further supports the idea about possibilities for service co-development.

With the help of interviews and questionnaires we identified eight key features of the neighbourhood. We argue that these key features should strongly be considered when developing the region and its services. The features are as follows:

- 1) Availability of nature: Sufficient existence of nature in the vicinity of the built environment. The nature is in good condition and outdoor activities are alleviated by trails and illumination.
- 2) Prevention of social displacement: Activities which prevent the lack of economic resources, social isolation and the limitation of social and political rights.
- 3) Multiculturalism as strength: The opportunity for a person with different cultural background to adapt to Finnish culture and simultaneously follow his/her own cultural traditions.
- 4) Child friendliness: An environment which is safe and provides stimulations for children and is good for families with children.
- 5) Sense of community: Local communality, in which it is essential that people know each other and have common activities. Is related to social safety.
- 6) Ecological life: Residents can organise their life in a way that it consumes considerably little natural resources and that the carbon footprint remains low.
- 7) Attractive living environment: Aesthetically attractive living environment providing also feeling of comfort for the residents.
- 8) Safety: An environment which is experienced as safe and where the safety risks are minimised.

Also both workshops provided interesting results. The most important observation was that residents of Hakunila are highly interested in participating in developing the neighbourhood. The residents also seem to have a strong ability to take one step further from not only creating ideas but also to provide suggestions for how to bring the ideas into the level of realization. The sense of value and valuable service was clear and the importance of seeking synergies in setting up service. However only a few actors were able to formulate the co-created value



factors: mostly those actors who were involved in assessment or evaluation processes as part of their work or profession.

When it comes to further creating the ideas and service co-design, one significant problem seems to exist: even though there are several active associations and active individuals in Hakunila, the collaboration among different groups remains considerably low. This is partly related to another issue: the lack of available spaces. Providing a convenient space for different groups and associations to organise activities and form tighter networks could strengthen the possibilities for collaboration between both different groups and individuals.

Discussion, Conclusions and Acknowledgements

The study confirms that it can be highly important to, by different means, support services which increase social activities and interactions and which thereby decrease social risks. User engagement in service development can be beneficial as shared value will be created for several stakeholders, enabling upgrading of the image, identity, wealth and well-being of a neighbourhood. Participation in workshops for service development can improve the neighbourhood's identity and increase the sense of community. During a longer period of time this perspective contributes to the identity of the neighbourhood. The other strong observation made was that collaboration between different local actors can be very valuable and it might create synergy solutions. The study confirms that the collaboration between units of city governance is challenging and an effective dialogue between local actors and city actors remains unsatisfied, even though specific area level network development programs were running.

To overcome these challenges eight key features were developed for the Hakunila neighbourhood. We introduce the approach of developing a set of key features for guiding and supporting strong, target oriented collaboration between all actors, for the interest of the local neighbourhood and community. We argue that local features set the focus from inside-out for the collaboration and co-creation of value between different units of city governance and neighbourhood level actors (as shown in figure 1). Goals and city level strategies remain to be implemented outside-in, but they are also linked to local features.

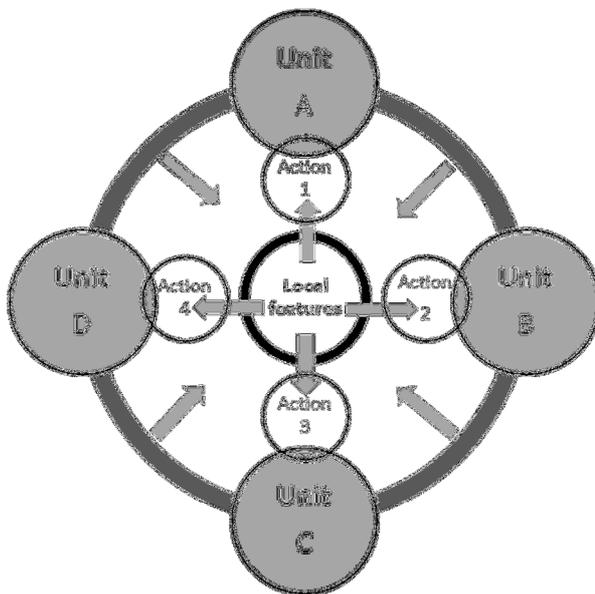


Figure 9. Collaboration between units of city governance and neighbourhood level actors guided by local features.

Figure 2 illustrates the role of different actors affecting the neighbourhood well-being and use value. We argue that the use value of the neighbourhood consists of quality of spaces and social interactions. Neighbourhood is characterised by its reputation, image, identity and brand. Three main actors can be identified: 1) Units of city governance 2) Citizens, interest groups and persons and 3) Entrepreneurs, third sector and associations. Units of city governance act in the scope of strategies but a more district level service focus and value assessment is desired. A significant problem is that the city units are continuously bound to a number of districts, and the services are related to daily and weekly needs. Collaboration of different city units can vary to a large extent depending on the service units and the city. The development needs of a district are considered only when this kind of a project has been initiated and budgeted, and also in this case, the different service units need to be included into the development teams.

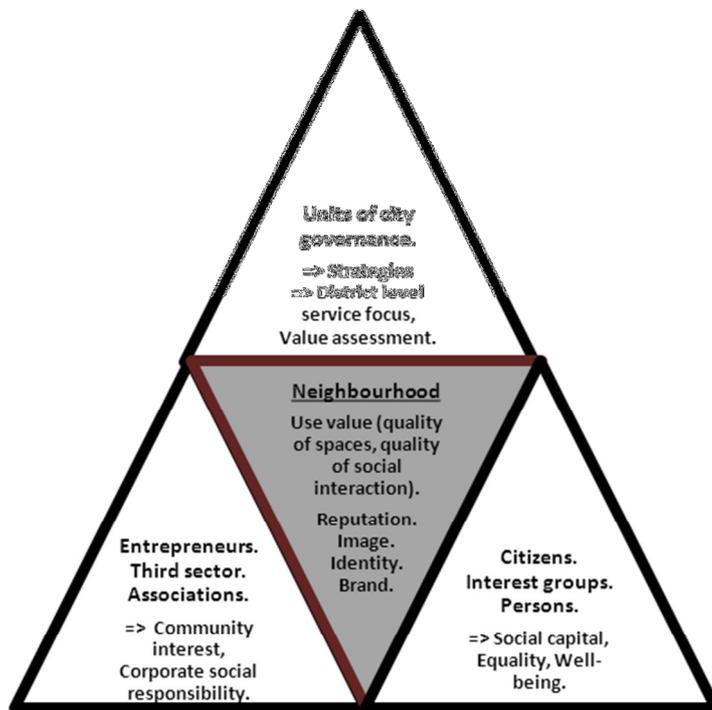


Figure 10. Actors around the neighbourhood level well-being and use value.

Different groups and active key persons increase social capital, and they support well-being of the local inhabitants. Citizens, in general, value neighbourhood by its reputation and brand. High community interest and corporate social responsibility of entrepreneurs, third sector actors and associations contribute to neighbourhood level use value. The idea of three main group of actors affecting neighbourhood well-being is related to the shared value theory by Porter and Kramer [6] which suggests that companies and society should co-operate in order to create not only economic value for the company but also social benefits for the citizens.

With the support of our case study we argue that three key elements are necessary for the co-operation and service co-creation to evolve. First, availability of facilities and open places where people can meet and change ideas is highly important. This is related to the second element, collaboration and informal meetings, which is essential for taking the ideas to the next, the implementation level. Collaboration can take place between different people but the collaboration of different associations might be even more important as the associations are already active but normally on a rather limited area. This leads to the third key element, the importance of a key person. Without an active key person, who is eager to bring individuals and groups together, implement actions and take risks, and who holds a personal interest in the wellbeing of the neighbourhood, successful forms of service co-creation are unlikely to evolve.



It is also important to note that before starting collaboration with residents related to services and social issues, it is useful to analyse the current service supply in the neighbourhood. Responsibilities to manage services are divided into several communal service and governance units whereas private services are independent. The analyses should provide a framework for collaboration with inhabitants as without this it is difficult to detect the aggregate service picture.

Heinonen and Ruotsalainen [12] point out three important questions/concerns considering the sense of community. First, how to avoid the uniformity often related to community feeling. The other question is, how to get citizens truly participate in forming groups and developing the region. And the third concern relates to the forms of activities. We like to argue that the same questions will arise in service innovations on community level. However, a successful participative process will lead to strong social impacts on different forms of well-being and equality, as well as strengthening the community feeling.

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Session 80:

Educating for a new paradigm. Are there barriers for the inclusion of this approach in formal education?

Chairperson:

Verdaguer, Carlos

Profesor Asociado. Escuela Técnica Superior Arquitectura Madrid, UPM



Living Labs in Architecture: Open innovation and co-creation towards a more sustainable architecture and lifestyle

Speakers:

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***Abstract:** Living Labs in Architecture can be tools towards a holistic knowledge generation and transmission, using real built environments for user-centred research and innovation as well as collaborative learning at a university campus and beyond.*

The present article describes existing living lab concepts and definitions, focusing on co-creation processes, methodologies for open innovation, and participatory learning approaches, with the LOW3 solar house living lab at UPC-Barcelona Tech as case study.

Outcomes and lessons learned can serve as example for similar initiatives, establishing Architecture Living Labs as open, collaborative learning environments, innovation arenas, and places of social interchange, empowering communities in their learning and progress towards a more sustainable lifestyle.

***Keywords:** Living Labs, co-creation, innovation, sustainable lifestyle, participation*

1. Introduction

Today society faces the need of empowering its citizens and communities towards a more active role regarding decision processes, which affect its economic, societal and environmental well-being.

The modification of the mechanisms of our socio-economic system, the setting of new goals and the implementation of new strategies which allow reducing the environmental impact of our society as a whole, together with the individual transformation of people's values, attitudes and behaviours, seem to be urgent to assure a healthy, prosperous and equal future for the present and all coming generations.

Nowadays the environmental impact of our lifestyles in industrialized countries is mainly related to housing, mobility and consumption. Technological solutions like energy efficient systems, products and services might contribute to the reduction of this impact. Nevertheless a whole transformation process of society is needed, and social innovations as well as behavioural changes are essential in these transformation processes towards a more sustainable society as a whole.

To experience alternatives, innovate in new ways of living and co-create scenarios for a more sustainable lifestyle, lighthouse projects, prototype buildings and generally places to meet,



learn and experience together can serve communities to build up this necessary knowledge. These projects can help co-creating new solutions as well as building up common future scenarios. They allow reflecting about and subsequently changing attitudes and behaviours.

On the other side citizens as users of technologies, products and services have been discovered as important contributors within innovation processes. User-centred research and user co-creation have been strongly developed and implemented during the last decade in order to accelerate research and development processes, obtaining user feedback through observation and evaluation in real-life environments or directly through open-innovation processes.

Living Labs are research and innovation infrastructures which apply this user-centred approach, bringing together different stakeholders in a physical place in order to generate within a real-life setting innovative solutions for technologies, products or services, offering a huge potential for creating holistic solutions for a more sustainable society.

2. Living Labs in Architecture as innovation tools between teaching and research

Applying the concept of a living lab to projects of sustainable housing prototypes in the context of academia, a specific type of Architecture Living Lab can be defined as a place for linking innovation to collaborative learning and co-creation activities.

This type of Architecture Living Labs can foster synergies between the knowledge triangle of teaching, research and innovation in the field of sustainable housing and lifestyle. In the context of local communities they can serve as multi-stakeholder platforms, fostering its transformation processes towards a more sustainable model of society.

Laboratories for construction, building physics or technological research and development traditionally focus on specific areas of knowledge and less on a holistic multidisciplinary approach. Their capacity to generate relevant output in fields like user acceptance of technology, user-technology interaction or the holistic impact analysis of technological innovations on life-style and society is therefore limited. The development of “Living Labs” has been a step forward in bridging this gap.

2.1 State of the Art

Since more than 10 years Living Labs evolve within the European R+D+I context as organizations which structure and provide governance to user involvement within “innovation arenas” where different stakeholders can experiment and innovate in real life environments.

Chesbrough (2003) introduced the term of Open Innovation describing the collaboration between internal R&D departments with external partners, benefiting from the generated synergies within a structured collaboration process. [1]



Shuurman et. al (2013) propose living labs as a common place where both forms of distributed innovation processes, open innovation and user innovation, can be brought together. These two forms of innovation would be linked through co-creation processes, as collaborative development of innovation among different stakeholders. [1]

Ballon et al (2005) defines a living lab as “An experimentation environment in which technology is given shape in real life contexts and in which (end) users are considered ‘co-producers’.” [2]

According to Almirall et al. (2012) this establishes a clear link to other forms of user participation in innovation processes like *lead users* or *open source communities*, which can adopt the role of the principal creators of innovation, whereas in the field of *user-centered design* users adopt a more passive role, giving insight or being observed for usability, human interaction or market validation exercises. [2]

Nevertheless the abundant literature about living labs, this particular approach to innovation today still seem to lack a clear definition beyond generic, descriptive parameters like user participation, user co-creation or multi-stakeholder innovation network. Despite of a great variety of living lab initiatives, their concepts and organizational structures as well as their specific characteristics are diverse and common frameworks for applied methodologies are still under development.

2.2 Living Lab Networks and initiatives

With regard to the Living Lab approach, several Living Lab networks and platforms have been founded since approximately the year 2000.

One of the fastest growing networks of Living Labs is the ENoLL (European Network of Living Labs). It was founded in 2006 and today (May 2014) has more than 450 Living Lab initiatives linked to it. EnOLL describes the need for Living Labs with the necessity of fastening the market availability of innovations through user-centred research and user co-creation. These concepts are based on the idea that, through immediate user feedback in real world environments, researchers and developers in collaboration with users are able to create and improve innovations and assure market viability within very short periods. This is an efficient alternative to traditional research and innovation processes. Only a small part of the ENoLL initiatives are focused on sustainable architecture and lifestyle, with a strong emphasis on social research and a culture of change.

In the last years, specific research and innovation infrastructures and projects have been created that focus on Net Zero Energy Buildings (NZEB) and Sustainable Lifestyle. One is the Norwegian Research Centre on Zero Emission Buildings at NTNU (Trondheim, Norway). It focuses not only on zero emission technologies but also on user behaviour and lifestyle. [3]

Another important initiative is the LIVING LAB project, a funded European FP7 project for Living Labs, directed by the Wuppertal Institute which had the idea of creating a network of



standardized living labs in different climatic and social-economic environments in Europe, thereby allowing the comparison of results through similar physical settings. [4]

2.3 Solar Decathlon Prototype Houses as potential living labs

Since 2002, the international Solar Decathlon competition promotes the development of energy self-sufficient solar houses by universities; fostering during the latest competitions, especially in Europe, a holistic view on sustainable architecture, including the aspects of urban density, shared facilities and infrastructure as well as energetic renovation processes. More than 120 prototypes have been developed and built during the last decade.

The efficiency of the Living Lab approach, together with the transdisciplinary and holistic concept of the Solar Decathlon solar houses define the potential of these prototypes for being converted into living laboratories in the field of sustainable architecture and lifestyle.

The following case study of the Living Lab LOW3 project at UPC-BarcelonaTech describes the specific concept for an Architecture Living Lab within academia, but with a strong link to the local community it is embedded in, and therefore with an extraordinary potential to support local learning, innovation and transformation processes.

3. Living Lab LOW3 – concept and outcomes

LOW3 is the 2010 Solar Decathlon Europe prototype solar house of UPC BarcelonaTech, which since 2011 serves as Living Lab for sustainable architecture and life style at the ETSAV campus at Sant Cugat with the aim to offer a holistic platform for education and innovation based on user-centred research and user co-creation. [5]

3.1 Objectives and methodology

Living Lab LOW3 is defined as an open platform for teaching, research and innovation in the field of sustainable architecture and lifestyle.

Main objectives of Living Lab LOW3 are:

- Constitute an open innovation platform for user-centred research and user co-creation in a real-life environment (prototype solar house)
- Install regular educational activities for Higher Education with extension to society
- Link applied research and innovation activities with companies in the field of sustainable architecture and life style
- Create a social platform for interchange and collaboration in the field of sustainable architecture and life style
- Apply living lab methodologies and open innovation strategies with participation of multiple stakeholders (academia, industry, society, administration)



The aim is to link innovation to collaborative learning and co-creation activities, fostering synergies between the knowledge triangle of teaching, research and innovation in the field of sustainable housing and lifestyle.

The involvement of the city of Sant Cugat and the educational offers for secondary schools allowed collaboration in education for sustainability, opening Living Lab LOW3 to the citizenship of its municipality as another group of “users” beyond academia and industry.

3.2 Living lab activities

A huge variety of activities have been linked to LOW3 as living lab platform for sustainable architecture and lifestyle. Beside regular teaching activities within its academic framework, Living Lab LOW3 opened up to society through educational visits for secondary school, guided visits to general public of its community, specialized visits for experts from different disciplines, and the dissemination of the generated knowledge through broadcastings, the Living Lab blog and social media.

Through co-creation and innovation seminars Living Lab LOW3 contributed to the generation and further development of initiatives in the field of sustainability locally and also within an international context.

Projects reached from urban renewal projects for energy efficiency with self-employment and a strong social component, through cooperatives for sustainable local development up to existing businesses in the field of local, ecological agriculture and possible links to educative activities as well a collaborative project of *therapeutic gardening* for a neighbourhood in Barcelona.

Collective brainstorming techniques and co-creation strategies were applied to generate creative ideas. At the same time interesting networking opportunities were generated and social component of the seminar allowed personal conversations and contacts between the participants.

As a university living lab, three official Living Lab LOW3 courses and several complementary activities have been completed since 2011. The “LIVE AT LOW3” experiment – the house occupation with 2 students during 2 weeks and holistic evaluation of their lifestyle and impact through the participating student team – allowed the first real application of a user-centred research approach.

Collaboration in industrial research projects on concentrated solar power systems and energy storage in buildings generated additional knowledge and synergies amongs participants.

Several other activities related to teaching, projects and dissemination with more than 1200 participants in more than 3 years show the important contribution of Living Lab LOW3

Figure 2 shows the diverse activities linked to the Living Lab LOW3 project, from formal teaching and applied research activities, to co-creation seminars, social events, knowledge dissemination and non-formal co-learning activities.



Figure 2: Living Lab LOW3: Teaching, research and innovation activities regarding sustainable architecture and lifestyle

Each activity has been documented. An individual analysis and evaluation has been carried out in order to evaluate the success of each initiative, analyse the lessons learned, and gather information about possible improvements.

3.3 Outcomes and lessons learned

After more than 3 years of implementation, field experience and continuous evaluation, the following lessons could be learned from the Living Lab LOW3 project:

- SDE prototype houses like LOW3 are ideal objects to be converted into Living Labs for sustainable architecture and lifestyle at universities, but proven methodologies and documented experiences on strategies, tools and outcomes are still rare.
- Living Lab LOW3 facilitates the generation of participatory co-learning activities that allow collectively generating and distributing new knowledge.
- A dynamic learning environment with formal and non-formal activities from workshops and seminars up to co-creation seminars, user-centred research activities and knowledge dissemination for the general public has been created.
- Living Lab LOW3 opened up to society supporting the knowledge generation on important matters like sustainable architecture, sustainable lifestyle and smart cities.
- Indicators are needed to describe and compare Living Lab projects and their structure, allowing benchmarking of different Living Lab initiatives.



4. Conclusions

Open innovation and co-creation towards more sustainable lifestyles of our society need a multistakeholder approach and university-society collaboration with a holistic vision and new methods and tools.

Collaboration, co-creation or synergies cannot be forced to happen within the diverse context of universities and local communities in general. Nevertheless, places and infrastructures can be created that facilitate these essential processes. Architecture Living Labs might be places, which foster this kind of processes.

Further development of the relatively new Living Lab approach is necessary. Methodologies and tools are in constant change, and experiences on national and international level will generate new knowledge that helps evolve the initial concepts.

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Real Life Learning Lab Approach in Sustainable Building Education – EURL3A Pilot Project

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Abstract: *To achieve wide implementation of sustainable Near Zero Emission Buildings (NZEB), education, business and research institutes have to cooperate more closer and try to attract more young students with innovative learning approaches. Also business partners have to be involved to transfer the latest research knowledge into practice and to provide practical feedback.*

The main objective of the European Real Life Learning Lab Alliance pilot project (EURL3A) - is to encourage structured, result-driven cooperation ventures between universities, research institutions and companies, bridging the gap between the sectors in the field of sustainable building. The EURL3A project developed the Real Life Learning Lab (RLLL) concept in three European countries as a start for European network of Knowledge Alliances (KA). Six partners from the Netherlands, the Czech Republic and Slovenia created the consortium. The paper summarizes the first outcomes and experience of the Knowledge Alliance concept.

Keywords: *education in sustainable building, Technical skills, transition towards a Near Zero Energy built environment*

Introduction

In order to meet the European targets on reducing the green-house gasses emissions and in order to reduce the dependency of scarce base materials and fossil energy sources, one of the most complex challenges is the transition towards a sustainable and Near Zero Emission (NZE) built environment. To encourage the process, education in technical branches has to be adjusted to the actual needs.

The distinctive feature of many European universities and higher education institutions is to be a front runner and a shining example in sustainability. Higher education institutions should be strengthened by taking the lead on cutting-edge research, action, and demonstration projects that will catalyse investment and drive the development of new markets. They have



furthermore an important contribution to make to the global response to climate change. The in-house knowledge can be brought into practice and at the same time sustainability can be embedded in education, shaping future green entrepreneurs for the building sector. In facing this challenge both the educational as well as the business sector encounter following barriers in implementing sustainable and NZE building and retrofitting technologies:

- The number of „technical“ students, crucial for this transition, is decreasing dramatically;
- The fragmentation of knowledge necessary for this transition;
- The skills of today’s delivered students do not match with the needs of the business sector in this field.

The analysis of needs identified one of the most important market barriers in Europe, i.e. the lack of an integrated approach of energy design in and between buildings. It is still not common for architects and engineers to work together in integrated teams. Due to this, a traditional fragmented design process is followed. Engineers and experts needed in this process are involved too late in the design process. This leads in most cases to inefficient solutions, not optimized buildings and higher costs due to extra measures for integration of energy efficiency measures and renewable energy systems.

The building sector in Europe needs to find solutions for this barrier, in order to come to Nearly Zero Energy Buildings. Therefore there is currently a substantial need for practitioners like architects and engineers to be specifically trained and educated in the integral sustainable design approach and who work in integrated multidisciplinary teams, addressing the integration of sustainable energy in buildings and built environment in general and as imposed by EU in its policies.

A barrier slowing down the transition towards a Near Zero Energy built environment is the way the education process is organized. In today’s situation after a pupil starts at an engineering University it takes about 8 to 10 years before engineering competencies are at a level bringing a substantial contribution to business. It is a general conviction that engineering theory and engineering taste are realized at the University and the real engineering practice is being realized in industry.

However, the fact is that it is hard to form engineering skills only in a school environment, since universities create with great difficulties a real production environment, where students could develop practical skills. On the other hand, industry does not emphasize these engineering skills enough, because industry believes this to be the task only of universities. This results in a longer period transforming young students into competent professionals in the new markets and the education process is not efficient enough.

EURL3A project and Knowledge Alliance concept

The EURL3A project [1] wanted to tackle the barriers by improving technical education in the sustainable building field, making it more efficient and attractive by a dynamic integration



of practice and theory and by integration of cutting edge innovation and latest research results by the so called Knowledge Alliance (KA) and Real Life Learning Lab (RLLL) concept. The project started in January 2013 and was finished in August 2014 as a pilot project. Six partners from three EU countries (the Netherlands, the Czech Republic and Slovenia) have been involved in the project.

The Knowledge Alliance (KA) concept is based on strong and structured partnership among education (students, teaching staff) – research (innovations) – business (driving force). From each country one high education institute (ZUYD Heerlen, Czech Technical University in Prague, University of Ljubljana) one research institute (NEBER, UCEEB, IRI – UL) and one business partner (Huygen, VUPS, Metronik) created the local KA. The research institutions in this case are organizational part of the universities.

RLLL – Real Life learning Lab concept

Core of the RLLL concept is the collaboration in multidisciplinary teams of students, teaching staff and researchers and business partners. They all bring in their competences and knowledge and take out what benefits for them. Students gain in competence of applying knowledge in practice, teaching staff gets more experienced in working in professional business settings and have input to update the curricula, businesses and young entrepreneurs are supported with applied research accelerating their innovation process and in expanding their (starting) business. The alliances realized knowledge exchanges by means of:

- Students of different faculties working together in multidisciplinary teams;
- Internships for students at the companies of involved business partners ;
- Teaching staff doing (part-time) internship;
- Teaching staff and professors doing lectures for professionals;
- Professionals of involved business partners working in RLLL teams;
- Professionals as guest lecturers in the universities.

Developing of Real Life Learning Lab Concept

In Real Life Learning Labs (RLLL) multidisciplinary teams of students and young entrepreneurs – under mentorship of professionals from universities and industry – worked on Real Life assignments from the business sector. During the process relevant theoretical knowledge was educated just in time. Within EURL3A project each university developed a Real Life Learning Lab that was used as a: (i) testing and training platforms together with the collaborating partners business sector; (ii) incubators for fostering and encouraging new green entrepreneurs in a permanent learning and research environment. Students have worked on those topics for their semestral works, projects, master or doctoral theses. Participation of researchers and professionals was also linked to the topic of the local RLLLS

RLLL in the Czech conditions was tested on the topic UCEEB-Multipurpose Office Building (UCEEB-MEB). This building is being designed in cooperation with UCEEB – University Centre for Energy Efficient Buildings, CTU in Prague. It is an experimental building dedicated to a full-scale research projects.

For Zuyd and IRI-UL these buildings have been recently realized. The activities of the RLLL at the University of Ljubljana are situated within several physical objects, i.e.: main university building is a historical building, which serves as a RLLL where different principles and technologies suitable for holistic refurbishments were developed. Self-sufficient Living Cell served as the second example. Another example is the Research unit OLEA. It is low energy self-sufficient mobile unit demonstrating new concepts of low energy technologies on the basis of locally available renewable sources.

In the Netherlands conditions the District of Tomorrow was used as the local RLLL. It is an innovative programme in which educational institutions, researchers, businesses and public authorities join together to create an exciting environment for the transition to a sustainable built environment at the European Science and Business Park Avantis in Heerlen/Aachen. This innovative programme involved designing, studying, and testing sustainable technologies so that they can be utilised “tomorrow” in towns, neighbourhoods, and buildings within the Meuse-Rhine Euregion.



Fig. 1: RLLL CZ: Visuallization of the UCEEB Campus in Bustehrad with UCEEB MEB in the background and UCEEB experimental area EA in the front (left). RLLL SI: Main Buildinh of the Univesity of Ljubljana (middle), RLLL NL: The District of Tomorrow (right).

Innovative educational character of the RLLL concept

The RLLL concept represents a new innovative approach for the dynamic integration of theory and practice in RLLL. The concept is to integrate the classroom within a professional environment, where learning and teaching is combined with practical work experience and exposure to the needs of industry. Research, innovation and education activities integrated in an open innovation setting, where students, teachers and professionals work together on new technologies.

By introducing an industrial and professional environment within the curricula the theoretical body of knowledge of a study is better aligned with the needs of enterprises. By combining theory with practical cases innovation is supported by the latest knowledge and the curricula are adjusted continuously to the markets demands. Students can develop their competencies by working on real life practical cases in an increasing part in their activities and with greater responsibility during their study.



Development and deployment of curricula

One of the objectives of RLLL development was to customize current curricula in the field of sustainable building and integrated building design. Project outcomes from the IEE IDES-EDU project [2] were used as a base material. This project educates, trains and delivers specialists, both students and professionals, in Integral Sustainable Energy Design of the Built Environment. 15 European Universities were involved in IEE IDES-EDU project in the period 06/2010 – 06/2013 to develop curricula and training programs including new methods of teaching that would equip students and professionals to work within a multidisciplinary and interdependent problem-solving framework

The education material was customized by each participating Knowledge Alliance according to their specific identified needs. Experts from local companies in Slovenia, in the Czech Republic and in the Netherlands working in the field of sustainable building were involved to give relevant feedback of the real needs and educational skills in building practice. The sample of 68 companies - 15 from Slovenia, 32 from the Czech Republic and 21 from the Netherlands – were involved in this survey and filled out the questionnaire mapping required skills in the field of sustainable building. Quite significant national diversity has been recognized among experts and professionals from each country. The results of this part of the project were used as a recommendation for teachers and professors at three participating Universities and were incorporated in lectures and seminars.

Organisation of exchange programs and structured mobility

One of the core tasks of the RLLL concept was to organize an exchange and mobility program for students, teaching staff and entrepreneurs both within the alliances themselves as well as between the three alliances for students. The main task of the international exchange program within EURL3A project was to prove innovative teaching and training methods for students and post graduates/experts in practice by implementing the local RLLs.

At the local level internship in companies, seminars and trainings for students (at bachelor, master, Ph.D. level), teaching staff and business partners were organized and local business partners were involved and participated in local RLLL projects.

At the international level 3 – 5 months internships for 24 students (8 per country) at one of the partner Universities was organized. The internship was designed as a “project internship”, participating students worked on Real Life assignments dedicated to the local RLLL. Also local business partners were involved and multidisciplinary teams of students under mentorship of professionals from universities and industry worked on Real Life assignments from the business sector and research field. Before the internship during the preparation phase students had to pick up a topic offered by the partner Higher Education Institution and advertised on the project web page. All the topics were always linked to the local RLLL. More than 70 topics were advertised. During the internship students worked on the topic. Also internships of students in the participating companies were organized.

Experience with RLLL approach at CTU in Prague

RLLL in the Czech conditions was tested on the topic UCEEB-Multipurpose office building (UCEEB-MEB). This building is being designed in cooperation with UCEEB – University Centre for Energy Efficient Buildings, CTU in Prague. It is an experimental building dedicated to a full-scale research projects. These projects will be focused on energy savings and management, controlling systems, advanced construction materials. Quality of internal microclimate will be measured. The building is going to be a part of experimental Micro Grid designed within the UCEEB area.

RLLL at the local level

Regular meetings of students, researchers and business experts on the topic of RLLL CZ: UCEEB-MEB have been organized within the EURL3A project. The main task of the meetings was to bring together students participating on this topic, researchers involved as experts in the design phase of UCEEB-MEB and companies involved in research activities of UCEEB. Almost 50 students from 3 Faculties of CTU (Faculties of Civil, Mechanical and Electrical Engineering) and from 6 study branches were involved in the design process. Three main topics were recognized as crucial for advanced design of UCEEB-MEB and three events dedicated to these topics were organized:

- Building, Energy and Environment, Resources and Waste Treatment, Energy Flows in Buildings;
- Architecture, Design and Environmental Quality of Buildings;
- Advanced Building Services Systems and Energy in Wider Context.



Fig. 2: Professional workshops (left), students workshops (middle) and final workshop from autumn school term 2013 (right).

The meetings were organized at two levels on every particular topic. Every topic started with so called “Professional workshop”. It involved several speeches and lectures given by experts - academics, researchers and professionals, who gave the students an insight to the contemporary trends in their field of expertise. The second part called “Students workshop” followed. Students were presenting their ideas from their field of expertise and discussed it across the technical branches under the mentorship of and professionals and researchers.

RLLL at the international level – students’ project internship within EURL3A project

The internship at CTU in Prague was held in the period 17th February till 16th May 2014. Eight students (6 from ZUYD University, 3 from University of Ljubljana) were hosted at CTU in Prague.

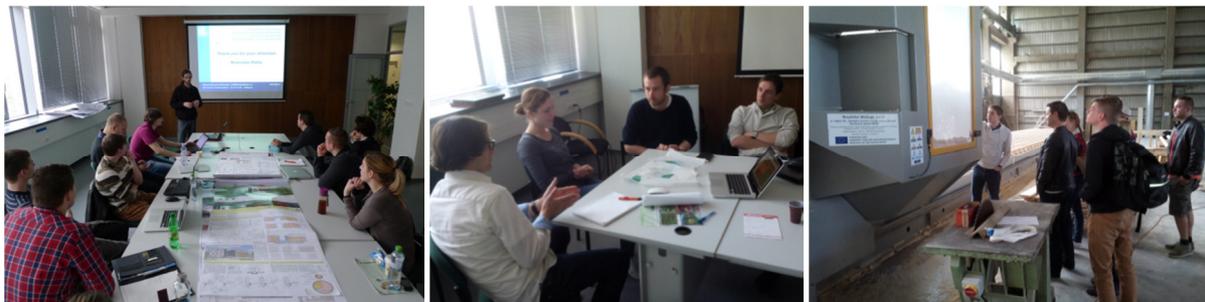


Fig. 3: The first meeting of foreign students who take part in the International Exchange program within EURL3A in Prague was held on Monday 19th February 2014 and presentation of business partner VUPS (left). Regular meetings during the internship (middle). Excursion in the timber structure factory (right).

Conclusions

The RLLL concept has shown one possible way how to encourage the transition process towards a sustainable and Near Zero Emission (NZE) built environment. Efficient education process in cooperation with latest research results and innovations and with positive feedback from building practice can force positive changes in the building sector. The envisaged impact is: (i) more and better educated and trained engineers on relevant technologies and competencies for the sustainable NZE built environment; (ii) support for enterprises in developing and innovating products en services to enter this market of tomorrow; (iii) an easy accessible network of knowledge and research capacity on an European level including an exchange and mobility program to support business growth; (iv) a contribution in speeding up the transition to a sustainable NZE built environment with respect for economic growth on a European level. The RLLL concept can be used also in other technical branches.

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MSc (Built Environment) curriculum for sustainable development education - a post graduate student's perception (Best Papers SB13 Africa)

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Abstract: Sustainable development (SD) has become a key focus of the legislative and societal movements across the world. This focus is a result of changing climate patterns, increasing number of natural disasters and environmental dilapidation amongst other. It is therefore extremely important to foster values and behaviours that could circumvent this situation. Incorporating SD issues within a curriculum provides an ideal mechanism for achieving this goal. The main aim of this study was to reflect on the MSc (Built Environment) programme and by ascertaining the perceptions of past and present post graduate students who have enrolled for the programme. An online questionnaire administered to randomly select past and present students was utilised as the research instrument. The findings highlight that limited attention is being given to the SD agenda within the curricula. It was found that knowledge on environmental issues, specifically SD and design was superficial.

Keywords: Built Environment, Curricula, Sustainable Development, Tertiary Education

1. Introduction

The Built Environment is one of the major industries which alter the natural environment in significant ways (Ortiz, Castells and Sonnemann, 2009). Literature indicates that since the early 1990s, many environmental organisations have appealed to tertiary institutions to provide education for sustainable development (Hayles and Holdsworth, 2008). Fostering awareness, among students, of environmental problems caused by traditional building techniques and bringing attention towards appropriate ways of countering such strategies could be the starting point for sustainable development education (Kokkarinen and Cotgrave, 2010). However, current educational constructs rarely provide students with a true understanding of the impact their decisions have on the natural environment, to allow such a change to occur (Hales and Holdsworth, 2008).

Effective education for SD should prompt students to reflect on their learning and should thus lead to changes in values, attitudes and behaviours (Allen, Smallwood and Emuze, 2013). The study is undertaken amongst Construction Management, Property Economics and Valuation,



Facilities Management, Construction Healthy and Safety Management and Project Management students of a particular South African University. This paper is founded on research undertaken between January 2013 and 2014, and is based on work in progress for the duration of the research. The study was guided by the following research question:

'To what extents have the courses / modules in the MSc Built Environment addressed sustainable development?'

2. Sustainable Development

*The essence of the term 'sustainable' is that which can be maintained over time (Heinberg, 2010). This definition implies that any societal action that is unsustainable cannot be maintained for long and will cease to function properly at some point in time. The first known European use of the word sustainability occurred in 1713 in the book *Sylvicultura Oeconomica*, by a German forester and Scientist, Hans Carl Carlowitz (Heinberg, 2010). The Brundtland Report from the United Nation's World Commission on Environment and Development defines SD as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs (Heinberg, 2010; Payne, 2010).*

The concept of sustainable development has since evolved from its infancy and currently includes principles of natural resource efficiency, waste management, pollution reduction, green building, recycling and the rehabilitation of the environment (Sassi, 2006). Future tenants of sustainable development include; an appreciation of the interconnectedness of environmental, social, political and economic aspects of sustainable development; understanding contested notions of sustainable development; problem solving skills; creative, holistic and critical thinking; self-reflection; and bridging the gap between theory and practice (Kagawa, Selby and Trier, 2006). The contribution of experts and academics in the field through the use of a curricula designed to focus on SD could have a positive effect in the endeavour to improve education and environmental attitudes of the Built Environment professionals of the near future (Thomas, 2004).

3. Drivers of change

The Built Environment is commonly associated with the decreased well-being of the environment, as it is seen as being immensely responsible for high levels of energy consumption, resource depletion and solid waste generation (Ortiz, Castells, and Sonnemann, 2009). The notion of SD is changing the way buildings are being commissioned, designed and eventually built (Hayles and Holdworth, 2008). According to Hayles, de La Harpe and Lombardo (2008), there is need for reduction of the amount of energy consumed by buildings and an increased need for the utilization of renewable materials that are not harmful to the environment. Built Environment clients are becoming more conscious of the benefits of SD, green buildings and the need to conserve the environment (Hayles, 2010). Furthermore, according to Hayles and Holdworth (2008), an informed client understands that green buildings do not only reduce operating costs, but also contribute to the attraction of young,



highly intelligent work force who prefer companies that demonstrate a commitment to the environment.

4. Implications on education for the Built Environment

Academia is the starting point in moulding built environment practitioners on how to contribute to the SD agenda (Murray and Cotgrave, 2007). This implies that, tertiary education built environment programmes should be primary responsible for imparting sustainable SD education. Education for SD directs educational tactics and content on the promotion, understanding and implementation of SD (Barraza and Robottom, 2008).

The most relevant aspects of SD to the built environment post graduate students is the incorporation of sustainability tenants at the design stages of the construction and planning (Cotgrave and Alkhaddar, 2006). The Built Environment graduates, who would eventually work with design contractors, would therefore be in a position to influence designer choice on construction material, systems and also promote sustainable practices from the design stages. One of the implications is that, it challenges educators to engage in a deeper understanding and learning about SD. According to Sommalsto and Brorson (2008), other topics that should be included in curricula are; environmental policy, strategic alignment, environmental aspects, procurement, the use of Information Technology and non-conformity reporting.

5. Methodology

To explore students' perceptions and awareness of sustainability and whether or not the MSc (Built Environment) curriculum promotes SD, a quantitative research methodology was used. The main question addressed in this research is 'to what extent have the modules in the MSc Built Environment addressed SD?' In order to address this research question, respondents were asked to indicate to what extent they agreed or disagreed with the following statements:

- *Research methodology promotes sustainability topics;*
- *Strategic concepts taught include sustainability issues;*
- *Sustainable development forms the nucleus of some modules;*
- *Climate change features in some modules;*
- *Social aspects of sustainability are present in certain modules;*
- *Environmental aspects of sustainability feature in certain modules;*
- *Economic aspects of sustainability are discussed in certain modules;*
- *The use of IT to address climate change is addressed;*
- *Lecturers refer to sustainable development challenges in classes;*
- *Elements of sustainable construction materials are included;*
- *'Strategic management' addresses sustainable development;*
- *Sustainable development is addressed in design management;*
- *Sustainable development is not mentioned at all in the programme and*
- *Sustainable development literature is recommended in courses.*

An online web questionnaire was administered to randomly select past and present MSc (Built Environment) students. Respondents were required to indicate the extent to which they agreed with a particular statement on a five-point scale; “strongly agree, agree, neutral, disagree, and strongly disagree.” Out of the 100 students requested to respond to the survey, 26 responses were received, indicating a 26% response rate. Out of the 26 respondents 6 (23%) were females.

6. Results Analysis

Most (65%) of the students agreed that the research methodology module promotes research that deals with sustainability. This indicates that the lecture is sensitive to the sustainable development topic and does encourage research in the topic.

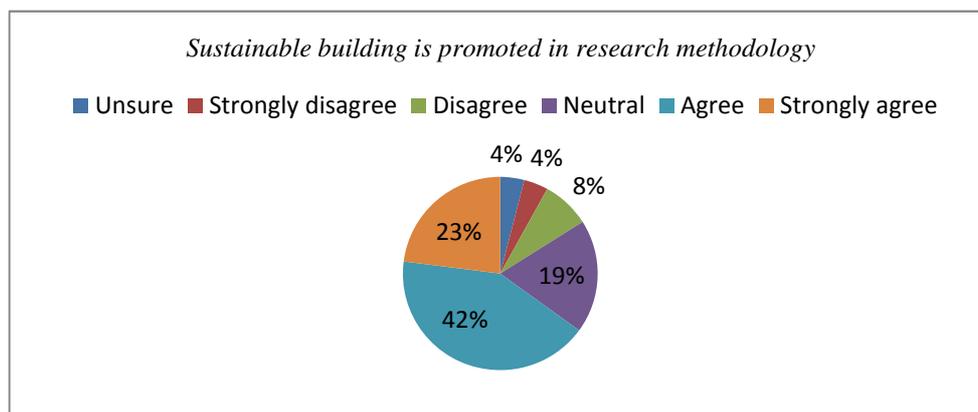


Figure 1 Distribution of respondents regarding the promotion of sustainable building

The study revealed 66 % of the respondents agree that strategic management concepts include the focus on sustainability within the built environment. However, 14 % of the respondents disagreed which indicates a need to pay more attention to SD in strategic management modules.

Responses to the statement, ‘sustainable development forms the nucleus of some modules’ indicate that 8% of respondents were unsure, 4% strongly disagreed, 16% disagreed, 20% were neutral, 44% agreed, 8% strongly agreed, and one respondent did not answer the question. The results imply that students do not believe that SD is the nucleus of some modules and more needs to be done.

The results of the study on the perceptions of students regarding the emphasis of the curriculum on the topic of climate change are in Figure 2 below. The results of the survey indicate that there is room for improvement in integrating climate change topics in the curriculum.

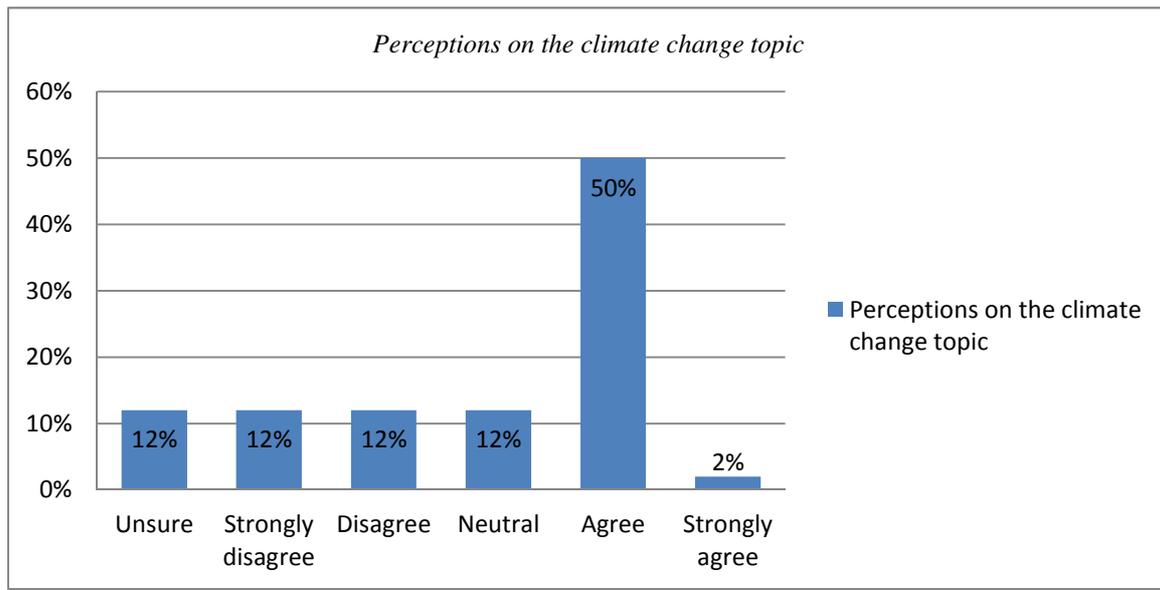


Figure 2 Responses regarding the focus of the curriculum on climate change

When students were asked to respond to the statement, ‘the social aspects of sustainability are present in certain modules, none of the respondents was unsure, 8% strongly disagreed, 15% disagreed, 23% were neutral, 46% agreed, two respondent did not answer the question and 8% strongly agreed. The results of the study show that most students do not think that social aspects of sustainability are present in certain modules.

When students were asked to respond to the statement, ‘environmental aspects of sustainability feature in certain modules’, 4% of the respondents were unsure, 8% strongly disagreed, 4% disagreed, 27% were neutral, 42% agreed, and 15% strongly agreed. The results show that most students agree that environmental aspects of sustainability feature in certain modules. The prevalence of the economic aspects of sustainable building in some built environment modules is emphatically confirmed by the respondents as is apparent in Figure 3 below.

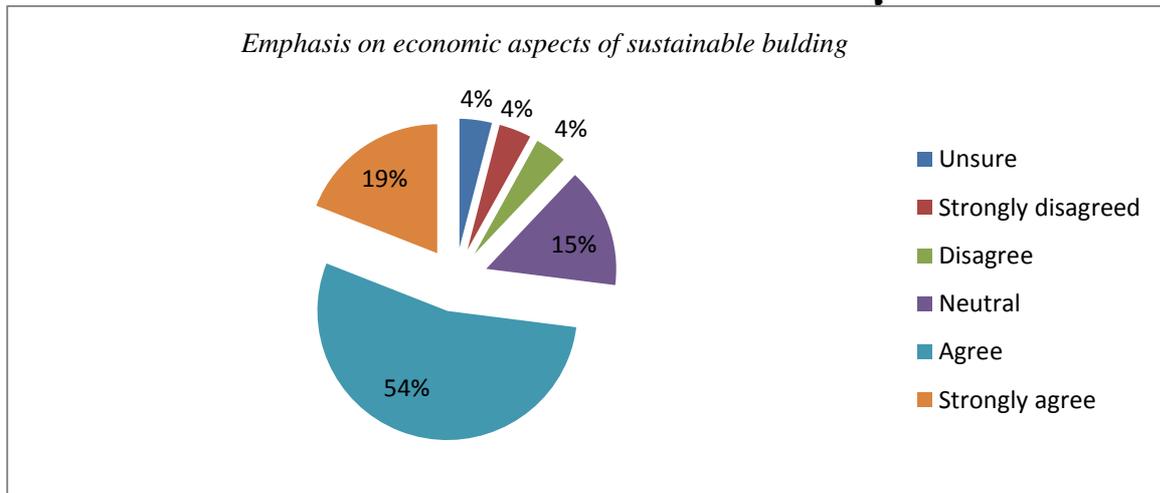


Figure 3 Respondents’ perceptions on the emphasis on economic aspects of sustainable building.

The results show that, most students agree that economic aspects of sustainable development are discussed in certain modules. This is because the specific curriculum under investigation has a specific Business and Construction Economics module which focuses on the economics topic within the built environment profession.

The IT module in the built environment curriculum lacks a focus on climate change mitigation as can be seen from the perception of the respondents in Figure 4 below. The result of the study indicates that there is room for improvement in integrating the IT module with the climate change topic within the built environment curriculum.

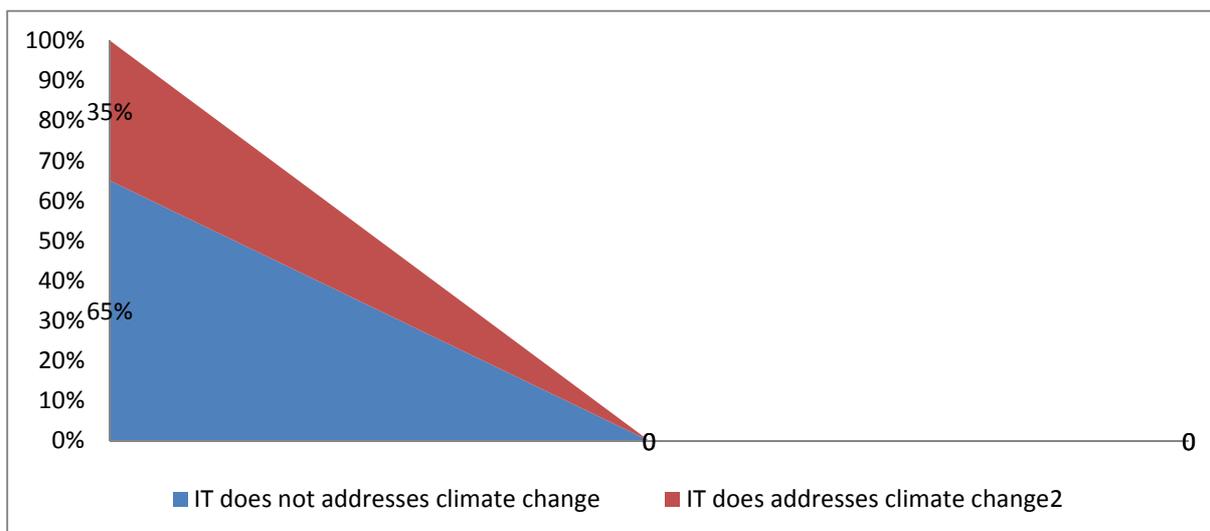


Figure 4 Students’ perceptions of climate change being addressed by the IT module



The responses to the statement that 'lecturers discuss sustainable development challenges in classes' yielded the following results: none of the respondents were unsure, 8% strongly disagreed, 15% disagreed, 15% were neutral, 58% agreed, and 4% strongly agreed. The results of the study show that most students agree that lecturers discuss sustainable development challenges in classes, but a more strategic approach is required as indicated by the lack of consensus from the results.

When students were asked to respond to the statement that 'elements of sustainable construction materials are included in some modules,' the results indicated that Masters' students generally agreed with this statement with a 52% affirmative response. Sustainable building requires a strategic approach from all role players more especially from top management. 50 % of the respondents indicated that a notable inclusion of the sustainable building topic was observed in the strategic management module. This confirms the earlier findings that strategic management module is inclusive of sustainability issues.

When students were asked to respond to the statement that 'sustainable development is addressed in the Design Management module', 12% of the respondents were unsure, none of the respondents strongly disagreed, 12% disagreed, 22% were neutral, 42% agreed, and 12% strongly agreed. The results show that most students agree that sustainable development is addressed in the design management module, but there could be more emphasis.

In the study, respondents were asked to respond to the statement that 'sustainable development is not mentioned at all in the programme.' None of the respondents were unsure, 42% strongly disagreed, 27% disagreed, 15% were neutral, 12% agreed and none of the respondents strongly agreed. The results indicate that part of the curriculum addresses the sustainable building topic. However, no stand-alone module deals with this aspect, hence there is no consensus. The students who believe that sustainable building is mentioned in the programme could be referring to the research methodology module.

On the question whether sustainable development literature is recommended in modules, none of the respondents were unsure, 12% strongly disagreed, 12% disagreed, 22% were neutral, 35% agreed, and 19% strongly agreed. These responses indicate that more sustainable development literature needs to be prescribed to students to advance SD education amongst MSc (Built Environment) students. Responses on the open-ended questions regarding how sustainable development concepts and topics can be addressed in the MSc (Built Environment) programme yielded great insight and alluded to the need to have a separate SD module within the programme.

7. Conclusions and Recommendations

SD is considered a critical component of the future wellbeing of the human planet. While sustainable development cannot be realised only through the demand from the market, higher education in particular is seen as a focal point to help in promoting sophisticated, action-orientated teaching and learning regarding sustainability as well as creating sustainable solutions for climate change. Of the many human activities associated with climate change,



the built environment offers the largest cost-effective potential for significant long-term reduction in greenhouse gas emission with substantial contribution to mitigating climate change. The inclusion of climatic behavioural factors in the design of buildings will significantly influence energy consumption in urban buildings and construction projects.

In order to acquire the necessary skills in built environment, teaching and learning at tertiary level should incorporate SD, green building, and environmental topics. The empirical results of this study show encouraging signs that MSc (Built Environment) students recognise the importance of appreciating SD. Relevant tertiary institutions should develop a specific module to address SD with emphasis on design, planning, construction, social impact, economic considerations and maintenance of buildings. There has to be an institutional drive and commitment to take part in sustainable development from the perspective of institutions of higher learning.

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Environmental design process at the facility planning and management offices in the national universities in Japan

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Abstract: *There are many old building stocks in universities, and renovation plan for these stock are implemented in these days in Japan. This study focuses on process and structure of environmental information flow within a facility planning and management group in universities. A questionnaire survey conducted to all national universities, and got response from 65 national universities. The questionnaire covers following items; Structure of planning and management group, Importance of environmental information, Decision making process within the group, Environmental information for design stage, Environmental information for design team, Effective environmental information for mechanical, Effective environmental information for lighting systems. The survey results show that there is lack of sharing environmental information within the group, and very few information at the early design stage and most of environmental information shared final design stage. This study conducted a case study and provided primary information of LCE, LCCO2 and LCC for university buildings.*

Key words: *University, FM office, Design process, Environmental information, LCA*

1. Background and purpose of the study

Ministry of Education, Culture, Sports, Science and Technology (MEXT) raises "Sustainability: realization of the education study environment that considered the global environment" as one of the development policies in the national universities, but the environment consideration renovation of university facilities does not progressing at the present condition.

This study focuses on the planning and design process in the renovation projects of the national universities and identifies issues for environmental performance and energy efficiency improvement of university facilities by investigating the actual situation.

2. Method

2.1 Survey

The study performed several surveys among the national universities, to understand the actual situation of planning and design process in the campus planning and facility management offices such as the organization form, the shared range and obtaining timing of environmental information for decision making at the selection of energy related equipment in the university buildings. It also analyzed the correlation with the energy consumption.

2.2 Renovation project process

The study illustrates the flow of renovation projects of national universities based on the document investigation survey on planning and design process.

2.3 Form of planning and management office, and Faculty staff involvement

The study conducted interviews to the Ministry of Education officials, and summarized the form of planning and management office and involvement pattern of architectural or building related faculty staff in the universities.

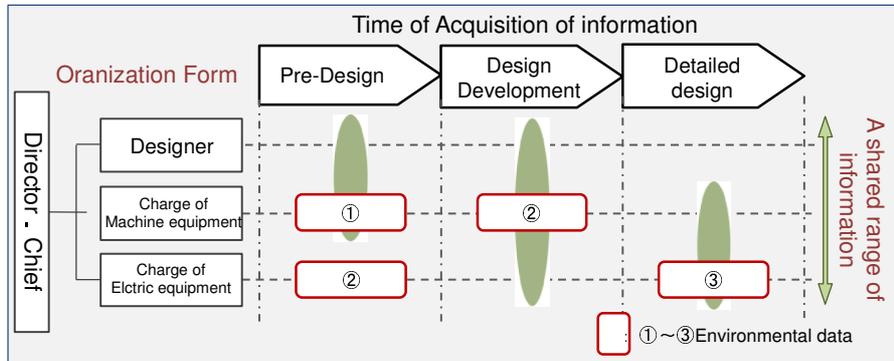


Fig. 1 Design process and organization form in the facility planning and management offices

Table 1 Type of organization form in the facility planning and management offices

	Form type
Organization form in the office	Process allotment type
	Planning and Specialized allotment type
	Complex organization type
	Other
Faculty staff involment type	Full time in the campus planning office
	Adviser
	Facilities Committee
	Involve by Project
	None

Table 2 Environmental Information used in the offices

	Environment information
Cost	Initial cost, Operating cost, Maintenance and Management cost
Reliability	Amenity (airconditioning), Lightning, Management of operation, Maintainability, Lifetime
Requirements	Energy use (Electric, Gas) (Air conditioning), Use daylight, Building information
Energy saving	Efficiency of energy systems, Control method (BEMS), CO2 emissions, Life cycle energy, Life cycle CO2
Other	

3. Trend of university building projects

3.1 Trend of the projects

The trend of the university facility development in recent years with the MEXT "Facility development record list (2008~2010)" shows that percentage of renovation overwhelmingly high compared to new construction. It is very important to introduce effective energy saving and environmental design for the renovation projects.

3.2 Cost of University facilities

Cost ratio of building, electric equipment, machinery were analyzed based on "Cost data of construction" from 1996 2001 of MEXT. The proportion of the building cost without mechanical and electrical systems occupies large portion without little change in the cost of



equipment to fiscal 2001. However the mechanical and electrical cost has not increased in recent years. Though the global environment issues are regarded as important, the investment of equipment and machinery relating to energy savings are hardly increased in the late years.

4. Questionnaire survey

4.1 Summary survey

The questionnaire survey was conducted on the planning and design process among all 86 national university's campus planning and facility management offices. The questionnaire responses were obtained from 65 universities (76% recovery). The questionnaire covers 7 categories, such as the form of planning office, type of faculty staff involvement, energy and environmental concerning, building type, renovation cost, environmental information and energy data of latest renovation project.

Table 4 shows the number of respondent universities. University classification is based on the MEXT's classification of the Universities by size.

Table 3 University type and respondents

University type	A	B	C	D	E	F	G	H	Total
	Large size	Mid-size (with hospital)	Medical college	Mid-size (without hospital)	Science and Technology	Humanity	Education	Graduate	
Respondants	10	20	4	8	11	3	7	2	65

Table 4 Questionnaires items

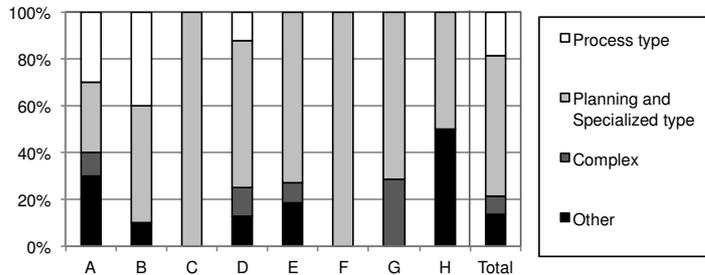
item		Contents
Organization Form		Organization form (See table 1)
Teacher's Organization		Faculty staff involvement (See table 1)
Consciousness in University		Consciousness on the environment and energy saving
Project	Building type	Humanities · Science and technology · Medicine · Welfare facilities
	Construction price	Construction price of building, mechanical systems and electric systems
	Environment data	Choose the choice factor of air conditioning and the illumination apparatus
		Choose acquisition time of Planning · Pre-Design · Design Development · Detailed design
		Choose shared range of Pre-Designer · Designer · Charge of mechanical systems · Charge of Electrical systems
Amount of energy	Choose the thing that is important for energy saving-related improvement and environment.	
		Amount of energy in community facilities (MJ/m ²).

4.2 Form of planning and management office and pattern of faculty staff involvement

Fig. 5 shows that the form of the campus planning and facility management office.

The study classifies the form of the office as follows; "Planning and Expertise type", "Process type" and "Expertise and Process type".

About 60 percent of universities, which responses to the questionnaire, is “Planning and Expertise type”, “ Process type” was seen in only medium-sized universities or more. Fig 6

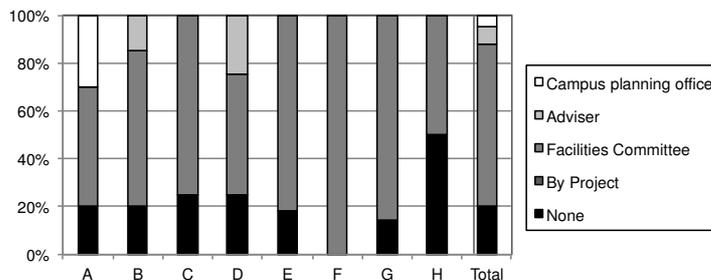


shows that the pattern of faculty staff involvement. A facility committee is the majority as the faculty staff involvement pattern, and a campus-planning office where faculty staff involves exclusively was seen in only large-scale university, faculty staff involves as an adviser was seen only medium-sized universities.

4.3 How to handling environmental information

Fig. 7 shows that the number of universities what kind of environmental information they use. The results suggest that the cost information relating to air-conditioning and lighting was used as a selection of the apparatuses. There was less number of the universities using information of life cycle energy and life cycle CO2 than other environmental information relating to

Fig. 2 Type of organization form in the offices



energy saving.

Fig. 8 shows that acquisition time of the environmental information of the mechanical systems. The information of operation and management for air-conditioning systems was obtained and discussed at early design stage, but other environmental information relating was obtained and discussed at latest design stage, or detailed design phase. The results of the lighting equipment showed similar trend.

Environmental information relating operating energy and CO2, lifecycle information is shared within each section staff in the design team in the facility planning and management office. However most of other environmental information is not shared within the section staffs (Fig.9). Respondents replied that effective information assisting energy saving is operating cost and energy efficiency equipment. It could not see much difference for the use

or non-use LCA information among the each form of the facility planning and management offices. The use ratio of LCA information at the planning and management offices where faculty staffs involve exclusively is high compared to the other type of offices.

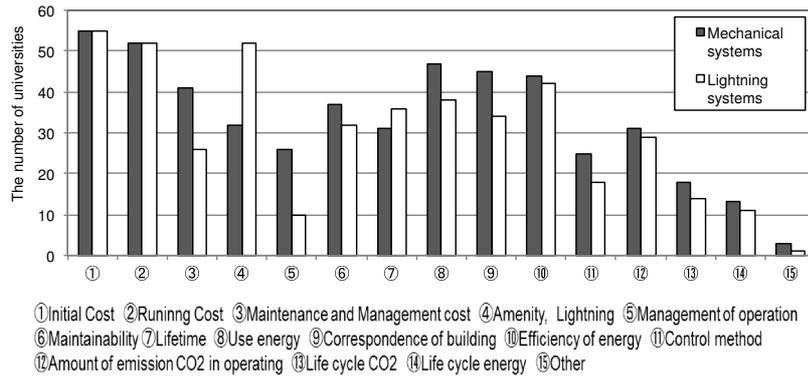


Fig. 1 Environmental information used in the offices today

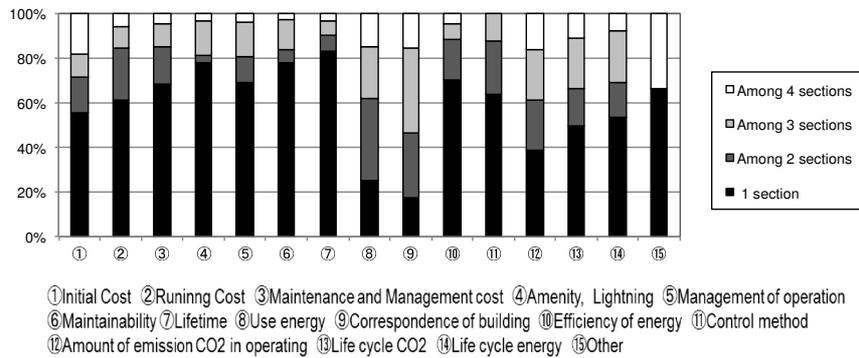
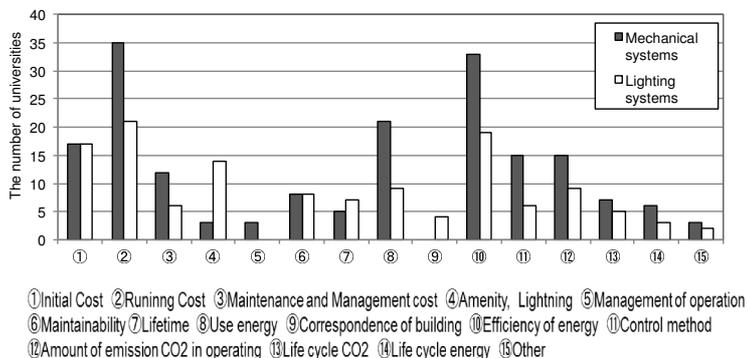
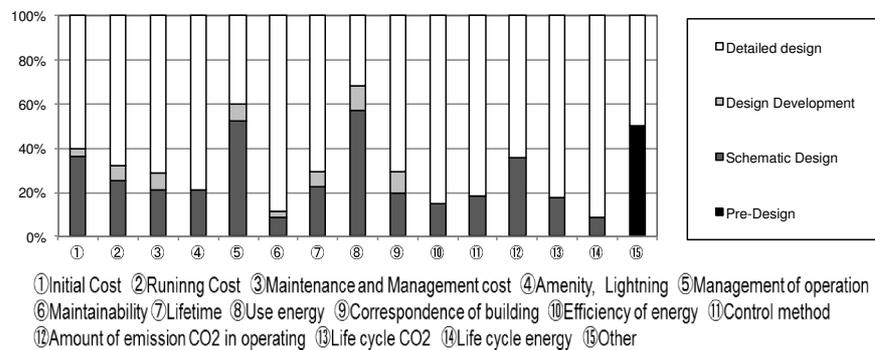
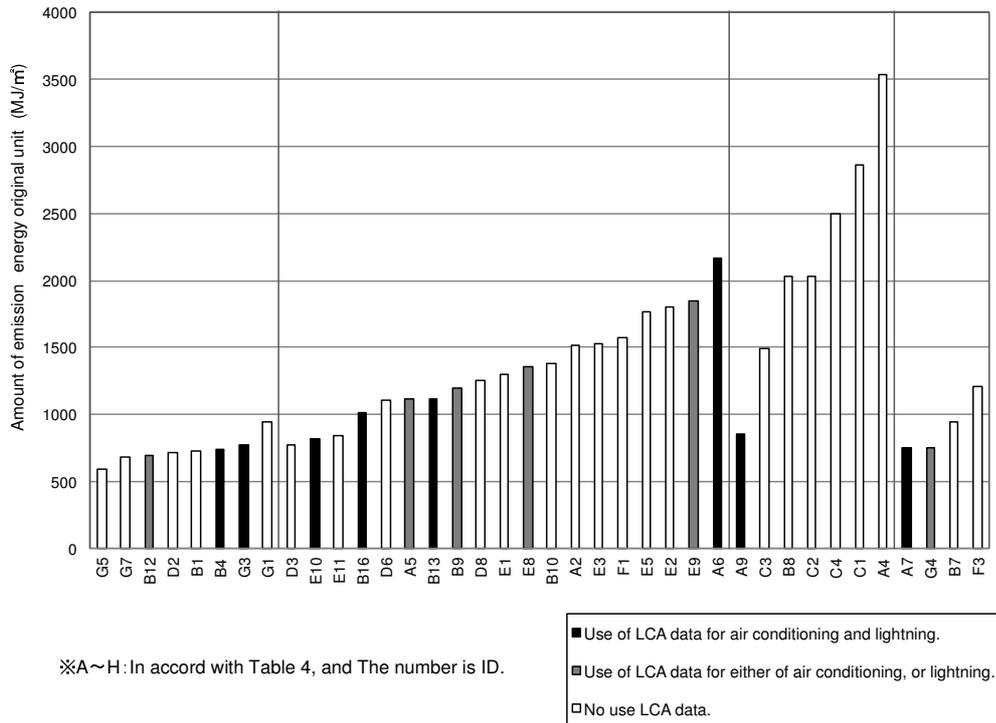


Fig. 2 Environmental information sharing in the offices today





5. Case study

5.1 Summary of case study

A case study is conducted to illustrate and verify LCA information providing procedure for renovation projects. A case study building is Department of Architecture and Civil engineering building in Utsunomiya University. Summary of building is shown in Table 5 and Case1 to Case 12 are shown in Table 7. Life cycle for renovation is assumed 25 years based on MEXT report.

Table 5 Summary of case study building

Name	Arc and Civil Building
Total floor area	4265.13 m ²
Structure, Floor	RC, 5F
Air conditioning machine	GHP (Partially ACU and GHP)
Lightning equipment	Fluorescent lamp 32W (Partially LED)
Heat insulating	Urethane foam. 25mm
Glass	Float glass 5mm

5.2 Results

One of the results of life cycle information is shown Fig.9. Table 7 shows that relationship among LCA information of building elements, design phases and task group that provides and deals with those information within the facility planning and management office.

6. Conclusion

The survey results show that there is lack of sharing environmental information within the group, and very few information at the early design stage and most of environmental information shared final design stage. Initial cost and operating energy are considered in most

of universities. However it is very little consideration on LCE, LCCO2 and LCC at design stage practice in campus planning and facility management offices in the national universities in Japan.

Table 6 Energy saving design menu

	CASE	Energy saving design menu
—	CASE1	Standard Model (Actual renovation model)
Equipment	CASE2	GHP→EHP (About the same performance)
	CASE3	HF Lightning→LED Lightning (About the same illuminance)
Building elements	CASE4	Heat insulating materials thickness 25mm→50mm
	CASE5	Float glass→Double glazing
	CASE6	Performance enhancement of heat insulating and glass (CASE4+CASE5)
Operational improvement	CASE7	Shortening of the air conditioning operating time (Stop at lunchbreak and after 19:00)
	CASE8	Shortening of the lightning use time (Stop at lunchbreak and after 19:00)
High efficiency	CASE9	CASE3+CASE4+CASE5
	CASE10	CASE2+CASE3+CASE4+CASE6
	CASE11	CASE2+CASE4+CASE5+CASE8
	CASE12	CASE2+CASE3+CASE4+CASE5+CASE8

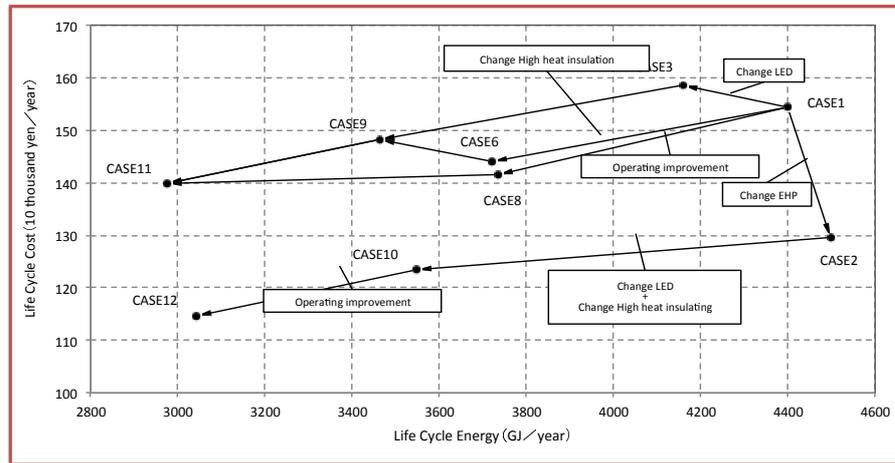


Fig. 9 LCA information example by using LCE and LCC diagram

Table7 LCA information through design process and data provision

		LCA information			Information provision section				Information obtain timing			
		Renovation	Operation	Maintenance	Planning	Building	Mechanical	Electrical	Planning phase	Design phase	Detail design phase	
Building elements	Orientation		○		○	○	○	○	○			
	Total floor area		○							○		
	Floor area		○				○	○		○		
	Ceiling height		○				○	○		○		
	Wall	Spec	○	○			○					○
		Thickness	○	○			○					○
		U-value		○				○				○
	Flooring	Spec	○	○			○					○
		Thickness	○	○			○					○
		U-value		○				○				○
	Ceiling	Spec	○	○			○					○
		Thickness	○	○			○					○
		U-value		○				○				○
	Roof	Spec	○	○			○					○
		Thickness	○	○			○					○
		U-value		○				○				○
		Area		○			○	○	○			○
		Blind		○				○	○			○
	Window	Cost	○			○	○					○
		Quantities	○			○	○					○
		Type		○			○	○				○
		Thickness		○			○	○				○
		U-Value		○				○	○			○
	Insulation	Area		○			○	○				○
		Blind		○			○	○				○
Cost		○			○	○					○	
Quantities		○			○	○					○	
Occupants			○			○			○			
Operating hours	Calendar		○		○				○			
	Operating hours		○		○				○			

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Session 81:

What should the keys to obtain efficient commercial buildings be?

Chairperson:

Bragança, Luis

iiSBE President / Professor at the Civil Engineering Department of University of Minho



An approach to the assessment of environmental impact in retail architecture

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Abstract

Architecture has been an essential resource in retail to keep products in suitable technical conditions, provide comfort to costumers during the purchase process, and set up a communication bond across the attraction process moves to trigger the purchase. The addition of more architecture in commercialization of products (stores, supply chains, etc.) has been an inherent fact to historical retail development in intensity and extent. However, a glance of the whole retail system in any city provide the verification of coexistence and development of many architectural typologies used for retailing, formed with dissimilar amounts of resources (energy, material, information, technology), that entail different environmental impacts.

Keywords: *urban retail, environmental impact, retail architecture, input-output analysis.*

1. Introduction

Simultaneously to growth of retail (1), the amount or architectural resources invested in product marketing also has risen, due to the increase in number and size of new models of shops: already in 2001, Harvard Design School quantified in about 2 billion m² the total retail area around the world (2). Experts say this increase is linked to development of trade activity, which has been bent on rise the sales capacity and the range on demand. Mass use of production systems, considerable amplification of supply (saleable product units and number of references), rivalry and changes in life standards, cause that the amount of architecture used in commercialization of products increases gradually. However, in any city, urban retail is composed of a range of architectural typologies that require uneven amounts of resources, and consequently, involve different environmental impacts.

The aim of this paper is to initiate in the identification of the impact associated to retail architecture considering in an environmental approach the resources that compound retail typologies (space available, structure, facades, building elements, furniture, energy, information), using as case study the city of Barcelona (Spain). Methodology includes a qualitative analysis of general issues of urban retail, and a quantitative analysis in which the amount of architecture used for retail in study cases is measured. Within the results obtained, it should be noted the development of a numeric model to assess the environmental efficiency of retail architecture (the relation between the obtained results (sales) and the resources employed (real estate investment)). Also, a ranking of retail architectural typologies is proposed, based in the simultaneous valuation of location, exploitation of urban pre-existences and architectural intensity (relation between architectural resources and m² available for the development of retail activity).

2. Achitectural diversity in urban retail: a living parallelism.

In the commercial system of Barcelona, it is possible to identify some peculiarities (fig. 1):

- In the same city coexist different retail architectural typologies, despite environmental and socioeconomic requirements are the same.

Some of architectural typologies found in Barcelona

Kiosks

Shops

Shopping centers

Markets

Peddiers

Vending machines

* Internet, mail, catalog, TV...
supercenters/warehouses

- Even some “ancient” architectural typologies remain in the city nowadays, because despite socioeconomic evolution still they are proficient to commercialize.

Market stands in Barcelona

- It is possible to find simultaneously the offering of the same product using different achitectural typologies, despite the functional requirements are the same for all of them.

Figure1. Coexistence of architectural typologies used for commercialization of products in Barcelona, Spain.

¿Why do exist different architectural formats that operate simultaneously in the same context, and even are used for the commercialization of the same product? To understand the guidelines that determine diversity of urban retail, it is plausible to compare with biological theories that explain the behaviour and the relation between natural species with the environment and among them, setting up a parallelism between retail as human system and an ecosystem: in ecosystem different organisms strive to survive in apparent balance, such as different retail “organisms” in the city attempt to pursuing the transaction (to produce commercial exchange to survive).

- Diversity of shapes guarantee the response capacity of the system facing all possible (new and unexpected) context requestings (economic, environmental, social). The system could lose its response if the multiplicity of architectural formats decreases, that means, its complexity as a system. For example, comparing the retail systems of Barcelona and Kaolak (Senegal) it can be observed that the Barcelona system is more diverse architecturally tan Kaolak’s. However, this is reciprocal with the range of possible context requestings, but it would be totally unstable and improbable in Barcelona, because the complexity and diversity of its context requestings is considerably bigger (seasons, global products commersialisation, health and security regulations, etc).

- Like a biological organism, it could be assured that an architectural typology used in retail progress to gain independence facing uncertainty, and improve its capacity of response to challenges progressively bigger. Therefore, some tipologies have progressed more tan others. Even functionally they are good for sheltering the comercial activity, they don’t have or don’t require the same capacity of response facing the same challenge (image 1).

selective pressure: to minimize the effect of climatic conditions in commercialization



Image 1. Progress in retail architectural typologies used in Barcelona.

• Natural selection is a filter that allows innovations favouring the independence of the organism facing context uncertainty. More complexity would guarantee more possibilities of survival. However, not in all cases the adaptation capacity of an architectural format for retailing is directly proportional to the amount of architectural resources, since this capacity depends on the selective pressures produced by any aspect of the environment. Like a natural system, complex organisms adapts easier to different variable conditions, but simple solutions also survive facing the different selective pressures (image 2).



Image 2. Adaptation of retail architectural typologies facing selective pressures.

3. The role of architecture in urban retail.

To understand the environmental impact associated to retail architecture, it is necessary to define the role of architecture in the commercialization process, from the identification and of different architectural typologies of retail premises (PS) in urban retail system (3). Typologies founded in Barcelona have been classified according to location, the use of urban pre-existences, and the real estate investment (figure 2):

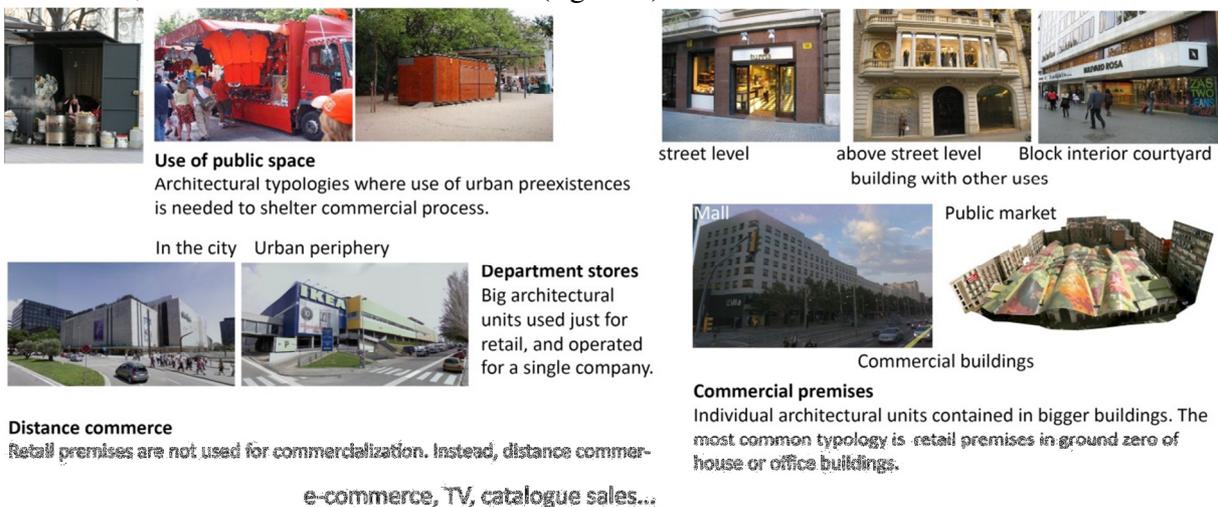


Figure 2. Classification of architectural typologies of retail found in Barcelona. In every typology it is possible to identify two main categories of functional requirements:

Shelter: minimum technical conditions that architecture should provide to allow the storage and exhibition of products and procure suitable conditions to commercial exchange (Table 1):

Product	<ul style="list-style-type: none"> - Preservation: protection of the product facing external factors that could modify their basic qualities (colour, texture, freshness, shape, etc). - Storage: stock availability to guarantee the satisfaction of demand fast and efficiently - Healthiness: exhibition and storage of products in hygienic conditions. This may vary according to the product and the socioeconomic context. - Safekeeping: protection against theft.
Commercial exchange	<ul style="list-style-type: none"> - Environmental control: environmental conditions (temperature, humidity) to commercialize comfortably. - Lighting: To guarantee general lighting conditions and to enhance the product. - Support: exhibition of products in a correct and suggestive way. - Form of sale: to provide the link between client and merchant according to the form of sale (personalized sale, self service, serve-over, etc). - Simultaneously offer: to benefit the offer of different products in suitable conditions. - Security, regulations compliance: to guarantee minimum conditions of security according to local regulations (evacuation, fire, etc).

Table 1. Functional requirements of retail architecture

Communication: PS increasingly assumes the function of comunicación platform between manufacturer and buyer. Through space compositional elements (Lighting, colors, materials, sounds, etc), PS attracts, persuades, seduces and convinces the buyer with the purpose of unleash the emotional process of purchase decision.

Architecture is a fundamental resource to respond to urban requestings (environmental, social, functional, regulations), allowing at the same time the development of commercial activity. All architectural typologies, regardless the amount of resources employed, should guarantee a minimum of shelter and communication conditions to make possible the commercialization of products. Even in typologies with low architectural intensity, pre-existing urban resources are used (lighting, streets, paraments) to shelter the commercialization process, always with complementary elements to guarantee minimum conditions. The investment of more architectural resources in PS (or a higher level or architectural response) allows to afford a more accurated responsiveness facing posible context requiements, satisfying at the same time additional needs in the commercialization process like storage and custody of products, attractive and suggestive exhibition of products, supplementary services, bigger isochronals, etc (image 3).



Image 3. Response levels of different architectural typologies.

4. Assessment method.

4.1 Background



Efficiency is the ability to obtain the planned objectives with **sufficiency** in the use of available resources. Considering architecture like material “input”, The **MIPS** method (Material Input per Service Unit) (4) enables to quantify the amount of material resources used during the life cycle of a product, including the resources needed to obtain the benefits of its use (5). P. Sinivuori (6) employed this method to assess two university buildings, defining that the service unit of a building is the **net useful area during a determined period of time (S = m²/years)**. An assessment of the materials invested in every building is done, obtaining a MIPS value in Kg resources/ net m²/year (a value linked not only to m² available, but also to **useful life** of the building). Similar approach is the methodology proposed by Albert Cuchí Burgos, P.h.D in the document “*Informe MIES: Una aproximació a l’impacte ambiental de l’Escola d’Arquitectura del Vallés*”(7): the environmental impact of the school of architecture is assessed, quantifying its energy cost during construction and useful life (energy needed to perform the school activities: lighting, HVAC, services, etc; in CO₂/year). This energy assessment is divided by **m² and the amount of university credits by year**.

4.2 Assessment method proposal.

Architectural Efficiency (**AE**), is the relation between a functional unit (turnover, business hours, satisfaction of shelter and communication requirements), and the amount of architectural resources employed in a PS to obtain those results [1]. The Architectural Intensity (**AI**) is the amount of architectural resources employed in a PS related to a functional unit **S** (m² available to the development of commercial activity) [2].

$$AE = \frac{\text{Obtained results (turnover, business hours, etc.)}}{\text{Used resources (AI: m}^2, \text{kg/m}^2\text{year, kWh/m}^2\text{year, complexity)}}$$

[1] Architectural efficiency

$$AI = \frac{\text{Architectural resources PS}}{\text{Funtional unit S}}$$

[2] Architectural Intensity

Considering architecture as a single resource, three units are defined to assess it like an input:

4.2.1 Material: consists of two measurable and noticeable elements:

A. Surface area: the space available to shelter an activity can be measured in m². In this case is evaluated only the surface of public access, named sales room (**SR**). This includes the space for exhibition and fitting of products, the payment area, information and customer services.

B. Weight: the space available for commercialization of products and its architectural fence are made of elements that weight and are measurable. Considering the useful life of each one of these elements (with their simultaneous service to another uses of the building), the intensity is determined in **Kg/m²/year** [3].

$$Kg/m^2 \text{ year} = \sum \frac{(Kg/m^2 C) * bc}{ul} + \sum \frac{Kg/m^2 SR}{ul}$$

[3] AI in weight of architectural elements

Where:
C: weight of container structure.
SR: weight of elements in sales room
bc: building coefficient
ul: multipliyng factor according to the useful life of every element.

4.2.2 Energy: is used in retail spaces for climate control, to emphasize products, to create determined environments through lighting, sounds and images, to use the different appliances (payment systems, conservation and measurement, etc).

Through architecture energy flows are canalized. Therefore, the energy consumption of a PS is due not only to the fuctional needs of the commercialization process, but also to the elements and architectural features in SR. Then energy AI is determined in **kWh/m²/year**, that is the amount of enegy needed for the development of comercial activity in a PS.

4.2.3 Complexity: architecture also is information. In PS architectural resources have an **arrangement** and an **order** that allow the satisfaction of shelter and communication in a specific manner. The level of complexity in a PS is its potential behavior diversity; and retail architectural formats will become more complex **to increase their shelter and communication capacity.**

To identify the complexity level of a PS a valuation scale is settled, considering possible shelter and communication requirements. Thus, to every architectural typology a level of complexity is determined considering a predominant functional criterion (shelter or communication), which compliance most of the architectural resources are intended.

This methodology has been applied in a sample of architectural typologies of PS detected in a working area of 1,00 km², intended for commercialization of two categories of products: bread (easy purchase decision/ usual purchase/low price); and women apparel (careful purchase decision/occasionally purchase/moderate price):

Table 2. Average Architectural Intensity (AI) per typologies and turnover range in commercialization of women apparel (font: author's compilation)

Typology	Name	turnover range	m ² Sprod	m ³ Sprod	kg/yr Sprod	kg/m ² per yr	kWh/yr	kWh/m ² per yr	Tendency
flea market		1	24,00	72,00	107,83	4,49	3,96	0,17	shelter
market stand	La Llibertat		12,00	26,40	429,80	35,82	421,20	35,10	shelter
second hand	Humana		132,29	330,79	2046,37	15,47	6249,49	47,24	shelter
outlet	Tot-hom	2	120,00	300,00	2797,50	23,31	12760,56	106,34	shelter
retail premises 20-150 m ²	Brownie		68,70	204,81	1924,44	28,19	8303,92	121,63	comm
	M212		60,00	240,00	2086,16	34,77	7458,24	124,30	comm
	erre de raso		80,00	240,00	2062,98	25,79	9541,84	119,27	comm
outlet	Alegrías	80,00	360,00	2401,42	30,02	10190,80	127,30	comm	
outlet	erre stocks	3	80,00	240,00	2065,29	25,82	11460,64	143,26	comm
Bazar	Casa Gracia		24,04	72,12	734,28	30,55	2225,84	92,60	shelter
retail premises 150 m ² +	Benetton		207,86	757,52	7010,72	33,73	24985,86	120,20	comm
	Mango	357,90	1252,65	12181,01	34,03	39352,50	109,95	comm	
	Adolfo Dom.	4	143,43	502,02	4127,27	28,77	16875,64	117,65	comm

Table 3. Average Architectural Intensity (AI) per typologies and turnover range in commercialization of bread (font: author's compilation)

Typology	Name	turnover range	m ² Sprod	m ³ Sprod	kg/yr Sprod	kg/m ² per yr	kWh/yr	kWh/m ² per yr	Tendency
Itinerant	artesanal market	1	4,00	8,80	33,74	8,44	99,00	24,75	shelter
	ocasional market		23,80	71,40	8218,90	345,33	4596,91	193,15	shelter
Internet	Matias		20,00	50,00	976,08	48,80	1378,60	68,93	shelter
Bakery + sale	Turris	2	44,80	174,13	2041,45	48,51	2887,52	67,44	shelter
	Bcn-reikjavick								
	Horno Fortino								
Oven + sale	Paul	3	35,00	122,50	1404,97	40,24	5543,32	158,23	comm
	Macxipa								
Sale + consume	La Boulangerie		3	19,33	65,12	760,93	41,23	2611,12	139,65
	El fornet								
	El molí Vell								
small supermarket	Alimentació	5	2,52	6,29	98,37	40,30	360,62	125,68	shelter
	Alimentació								
	Alimentació								
supermarket	Caprabo	5	4,27	14,95	179,85	42,30	598,74	129,90	shelter
	Dia								
Restaurant/ catering	Bopan	4	10,29	42,30	400,44	38,65	1305,11	155,59	comm
	Sant Joan								

Where:

Turnover range: billing average calculated according to IAE tax.

m² Sprod: m² of sales room SR

m³ Sprod: volume of sales room SR

Rep kg/yr Sprod: annual repercussion of architectural weight in Sprod

Rep kg/m²/yr Sprod: annual repercussion of architectural weight per m² of Sprod

kWh/yr Sprod: annual energy consumption in Sprod

Tendency: predominant functional category (shelter or communication requirements)

5. Conclusion

- The result of the development of commercial activity in PS is measurable, through the amount of commercial transactions (sales) carried out in a specific period of time. This value is used



to establish the profitability in a PS, through the relation between the resources employed and the obtained benefits. To evaluate the retail activity from an environmental scope, it is possible to define a similar equation, in terms of the amount of resources used to commercialize certain quantity of products, and the obtained results (transactions).

- In terms of architectural resources, it is possible to establish a method similar to inputs/outputs balance, where the amount of architectural resources employed to create commercial premises is measured. The viability of setting up this relation is supported with the huge architectural diversity of PS identified in the city: this reality proves that the same product could be commercialized in the same socioeconomic context using PS with different architectural intensities.

- The three measurement units proposed allow an architectural valuation in different dimensions: space available, material resources, energy consumption during useful life, information. From the Architectural Intensity (AI) it would be possible to outline, like others architectural uses (ie offices or educational buildings), some reference values to set up boundaries between sufficiency and over-measurement in the use of architectural resources.

- With the suggested method it is possible to assess architecture like a whole resource. However, architecture is also the result of a construction process, Then to propose a more accurate environmental assessment method, it is necessary to consider also material features and the consumption of resources in different construction process.

- Considering that most of the retail premises in the city are located in existing buildings, in the environmental assessment of the elements that compound the SR would be a broader scope. Therefore, it would be possible to suggest a supplementary assessment method in which the most suitable architectural typology is identified first, from the comparison of AI between options; and then to implement a more accurate study where environmental impact consequence of use of resources in conceptualization and useful life of PS is identified.

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Implementation of daylight as part of the integrated design of commercial buildings

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Abstract: Today, there is an obvious lack of sufficient integration of daylight in building design. The literature has been reviewed in order to see if knowledge exists to formulate an improved daylight design methodology which may be consistently integrated with thermal comfort and energy use design. Based on findings in the literature, a proposal is given on how daylight calculations and evaluations may be implemented throughout the building design. Important features in the proposed design are: early implementation of simulation tools, implementation of climate-based daylight modelling, and coupling between simulation tools for daylight, thermal comfort and energy use to ensure consistency in the design. The design proposal has been tested and the results show that the method might lead to a design with satisfying indoor environment and low energy use. Yet, more research is needed to validate and to set proper benchmark values for newly proposed climate-based daylight metrics.

Key words: daylight metrics, daylight prediction, discomfort glare, integrated design

Introduction

It may be a climatic challenge to design buildings with low energy use and high indoor environmental performance. Figure 1 illustrates how daylight, thermal comfort and energy aspects influence each other in a complex manner. There is a need for an integrated and consistent design approach to daylight, thermal comfort and energy use in order to be able to fulfil future energy and comfort demands.

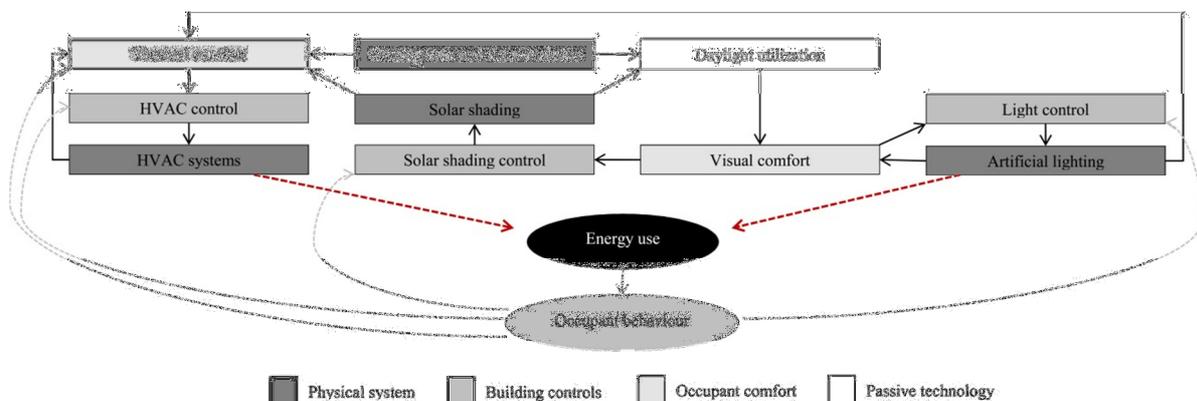


Figure 1: Illustration of interaction of daylight, thermal comfort and energy aspects.



At the present time, simulation tools are used, which makes it possible to evaluate both thermal comfort and energy use at the same time, yet there is an obvious lack of sufficient integration of daylight [1]. Daylight is an essential component within buildings both with its architectonic and aesthetic features and with its functional aspects. With regard to the latter, an effective daylight design combined with intelligent control for artificial lighting might lead to reduction of energy use for lighting and cooling, especially for commercial buildings where the occupied period usually coincides with periods of excessive access to daylight. Additionally, it is important to remember that daylight has positive health effects [2], and that occupants usually prefer daylight as their source of illumination [3]. These last features might actually be the most vital arguments for investing time and effort in daylight design.

However, several surveys conducted among building designers and researchers [4-6] reveal that far from all conduct daylight analysis during their design. The aim of the present paper is to propose how daylight design may be implemented throughout the design of commercial buildings as an integrated part of the building design. The literature has been consulted in order to see if there is existing knowledge to formulate a three step design methodology for integrated daylight design. The following sections present the results from the literature review followed by a test of the proposed design methodology.

Literature review of daylight design

With respect to an integrated design, criteria for daylight may be used to assess if the daylight environment is satisfying, if artificial lighting needs to be added or if there is risk of glare and need for activation of solar shading.

Is the daylight satisfying or do artificial light need to be added?

The daylight factor (DF) has existed since the beginning of the 20th century [7], it is used as a measure for satisfying daylight and is currently the most commonly used daylight metric worldwide [8, 9]. The daylight factor is defined as the ratio between the internal illuminance at a point in a room and the unshaded, external horizontal illuminance under a *Commission Internationale de l'Eclairage* (CIE) overcast sky [9].

As an isolated measure, the DF does not contribute with much information regarding the real daylight level in a room as it only considers the static CIE overcast condition. Under these conditions there might e.g. not be need for use of solar shading, which may explain why use of solar shading commonly is neglected in daylight design [10]. Yet, it is well known that solar shading is indispensable for office workers to control solar gain and glare and its use influence daylight supply, thermal comfort and energy use. Further limitations of DF are widely discussed elsewhere [9, 11], and one thing seems certain: new climate-based daylight metrics (CBDm) should be used in the future as criteria for annual daylight, a selection of CBDm are presented in Table 1.

The question is then which CBDm to use? UDI and $sDA_{300/50\%}$ might be preferable to use since they are developed based on occupant preferences in daylight environments. One advantage of $sDA_{300/50\%}$ is that the annual daylight level in the room can be expressed with

one single number and according to the Illuminating Engineering Society of North America (IES), $sDA_{300/50\%} \geq 55\%$ has to be met in order for a space to be nominally acceptable daylight. $sDA_{300/50\%}$ has been accepted as daylight metric by the IES as part of a methodology for evaluating annual daylight [12]. However, from an integrated design perspective, UDI seems to give more interdisciplinary information. The UDI concept is divided into four categories [13]; UDI_fell short (UDI-f, 0-100 lux) indicate the time when required illuminance has to be maintained by artificial lighting, UDI_supplementary (UDI-s, 100-300 lux) indicate the time when artificial lighting needs to be added to the daylight to maintain required illuminance, UDI_autonomous (UDI-a, 300-3000 lux) indicate the time when the light level can be obtained by daylight alone and UDI_exceeded (UDI-e, 3000 lux<) is associated with glare or overheating and indicate the time when solar shading might be needed. It might be a reasonable assumption that the IES threshold for satisfying daylight area of 55 % can be adopted for the UDI-a category as well.

Table 1: Selection of newly developed climate-based daylight metrics

Metric	Information in the metric	Lower threshold [lux]	Upper threshold [lux]	Comment	Reference
Daylight autonomy (DA)	Percentage of occupied time when a minimum work plane illuminance can be maintained by daylight alone.	500	-	Threshold commonly derived from standards for artificial lighting.	[14]
Useful daylight illuminance (UDI)	Percentage of work hours when daylight levels are useful for the occupants.	100	3000	Thresholds derived from literature study on occupant preferences in daylit offices. Upper limit is associated with glare/overheating.	[13, 15]
Spatial daylight autonomy 300/50% ($sDA_{300/50\%}$)	Percentage of analysis area that achieves the illumination threshold of 300 lux for 50 % of the analysis period.	300	-	Target value of 300 lux was derived from a survey with daylight experts and building occupants in 61 day lit spaces.	[16]

Is there risk of glare?

Nowadays, extensive use of computers in the working environment has become common. Consequently, the line of sight is more horizontal than for reading and handwriting tasks on the desk, which makes discomfort glare from windows a more considerable concern [17]. Discomfort glare produces discomfort without necessarily influencing visual performance and visibility and still there is a lack of knowledge about its underlying process [17].

At the present time there is no international accepted measure to evaluate the discomfort glare from windows and/or solar shadings. However, there are recommendations given in the literature [18, 19] towards use of the newly developed metric Daylight Glare Probability (DGP) [20]. One major drawback is that it might be very time-consuming to carry out an annual DGP analysis. In order to address this problem, Weinold [21] has developed and validated two simplified versions of DGP; (1) DGP simplified (DGPs) based on vertical eye illuminance and (2) enhanced simplified DGP based on vertical illuminance at eye in combination with a simplified image. The validation showed in general good results for the enhanced simplified DGP and reasonable results were seen for DGPs when no peak glare sources were present. In a design process, a glare analysis might be most suitable for the detailed design stage, both because the annual glare analysis is rather time-consuming and because glare is direction dependent and should be carried out at probable work stations.

Calculation procedure

Early implementation of simulation tools are indispensable in order to make annual evaluations of horizontal illuminance and glare. Simulation tools based on validated and effective calculation engines should be used. Yet, it will be almost impossible at the present time to totally avoid the use of rules of thumbs and simple static calculations in the early design phase to make the first design proposal. Studies have shown that not all earlier published rules of thumb may be trustworthy or suitable for today's building design [11]. It is therefore important to use validated methods which yield reasonable results. Reinhart and LoVerso [11] have suggested a validated sequence of rule of thumb to come up with the first daylight scheme for sidelit rooms. This sequence is based on the DF, with all its limitations, and do therefore only consider the diffuse daylight. Further into the design, yet still early design phase, it will be necessary to implement use of simulation tools in daylight design in order to carry out climate-based modelling and reach a more integrated design approach.

Design proposal

Table 4 compresses a preliminary proposal for a daylight design in three levels of detail based on findings in the literature. Important features of the proposal are early implementation of simulation tools and adoption of climate-based daylight modelling from an early stage, which straightens integration with thermal comfort and energy analysis.

Table 2: Proposal of how daylight calculations and evaluations may be implemented as an integrated part of the building design based on findings in the literature.

Design stage	Proposed method	Daylight evaluation metric
Initial design	Use the validated rule of thumb sequence proposed by Reinhart and LoVerso [11] to draw up the first daylight scheme to find minimum required glazing areas; -initial assumptions regarding wall thickness, window head height, room width (w), mean surface reflectance (R_{mean}) and visual light transmittance (τ_{vis}) of the glazing have to be made. Use an effective simulation tool to check that the glazed areas are consistent with annual daylight requirements for UDI-a as well as for thermal comfort and energy use.	DF/UDI
Schematic design phase	Use a climate-based daylight simulation tool to verify the chosen glazed areas and glazing characteristics when use of solar shading is accounted for. In case of dynamic solar shading, use a simplified solar shading model and utilize UDI-e (3000 lux) as a threshold for activation of solar shading due to glare/overheating. Exchange solar shading, lighting and occupancy profiles between daylight, thermal comfort and energy use predictive tools in order to achieve a model consistency for the integrated design.	UDI
Detail design phase	Keep using a climate-based daylight simulation tool, but if necessary make a more customised and product oriented simulation with respect to solar shading and installed lighting systems. Verify the daylight environmental quality with respect to useful daylight illuminance and glare.	UDI, DGPs/ DGPenhanced simplified

Test of design proposal

The design sequence is tested in design of a sidelit cellular office located in Oslo, Norway. It is assumed that the wall thickness is 500 mm (U -value= 0.10 W/Km²) and that the glazing is placed in the middle of the wall, which gives an obstruction to the sky angle (θ) of approximately 10°. Following room dimensions are set; floor to ceiling height = 2.75 m, window head height = 2.7 m and room width = 2.75 m. A glazing is selected with the characteristics; U -value=0.6 W/Km², g -value=0.49, direct solar transmission=0.41 and visual light transmission = 0.71. Internal gains and values for heating, cooling and ventilation are set according to the Norwegian standard NS3701[22]. Table 3 gives the requirements set for indoor environment and energy use and Table 4 shows the results from the different steps of the design. Daysim [23] is utilised for the daylight analysis and IDA ICE [24] is used for the thermal and energy analysis.

Table 3: Requirements for indoor environment and energy use.

UDI-a	≥ 50% for ≥ 55% of analysis area
Operative temperature (T _{op}) during occupant hour	21-26°C
Total annual specific energy demand	<70 kWh/m ² year
Specific energy demand heating	<20 kWh/m ² year
Specific energy demand cooling	<10 kWh/m ² year

Table 4: Test of proposed design

Initial design

Rule of thumb sequence, for details see [11]:

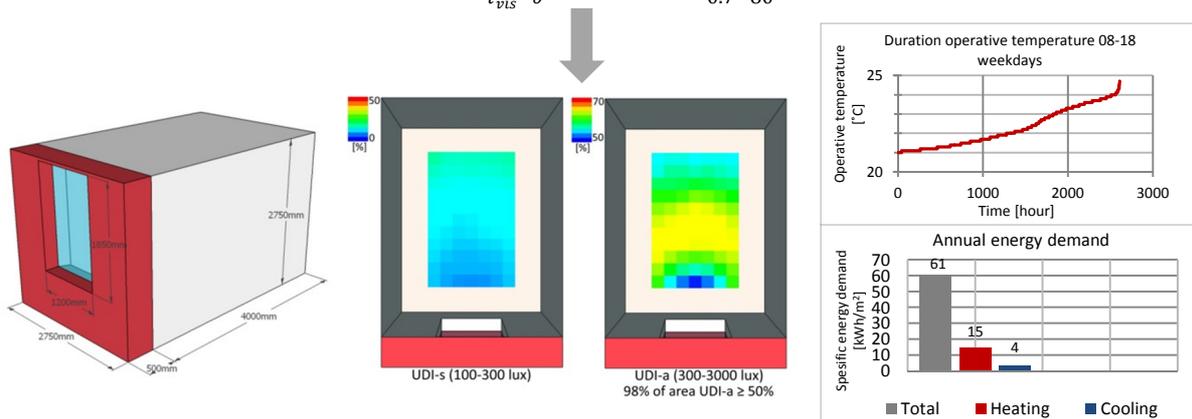
$$\text{Window to wall ratio (\%)} > \frac{0.088 \cdot DF}{\tau_{vis}} \cdot \frac{90^\circ}{\theta} = \frac{0.088 \cdot 2}{0.7} \cdot \frac{90^\circ}{80^\circ} = 0.28 \rightarrow \text{OK}$$

$$\text{Depth of daylight area} < \text{minimum} \left(\frac{\frac{2}{1-R_{mean}} / \left(\frac{1}{w} + \frac{1}{h_{window-head-height}} \right)}{(h_{window-head-height} - \text{work plane height}) \cdot \tan\theta} \right) = \left(\frac{2}{1-0.5} / \left(\frac{1}{2.75} + \frac{1}{2.7} \right) = \underline{5.4m} \right)$$

$$\left(\frac{2.7 - 0.8}{2 \cdot 2.7} \cdot \tan(80) = 21.7m \right)$$

Maximum depth of the daylight area is according to the rule of thumb 5.4 m. However, it is chosen to limit the depth of the cellular office to 4 m since this is a more reasonable size of a one person office; internal dimensions: 2,75m · 4,00m · 2,75m.

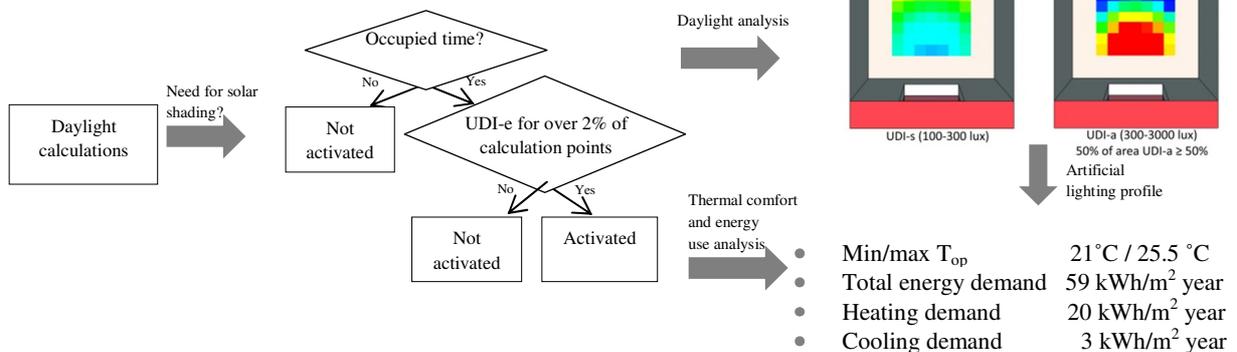
$$A_{glazing} = \frac{DF \cdot 2A_{total}(1 - R_{mean})}{\tau_{vis} \cdot \theta} = \frac{2 \cdot 2 \cdot 61.8(1 - 0.5)}{0.7 \cdot 80} = \underline{2,2m^2}$$



The initial design proposal satisfy the requirements for daylight, thermal comfort and energy use and is an acceptable design to develop further. Influence of consistent solar shading and lightig control will be evaluated in the following design stages.

Schematic design

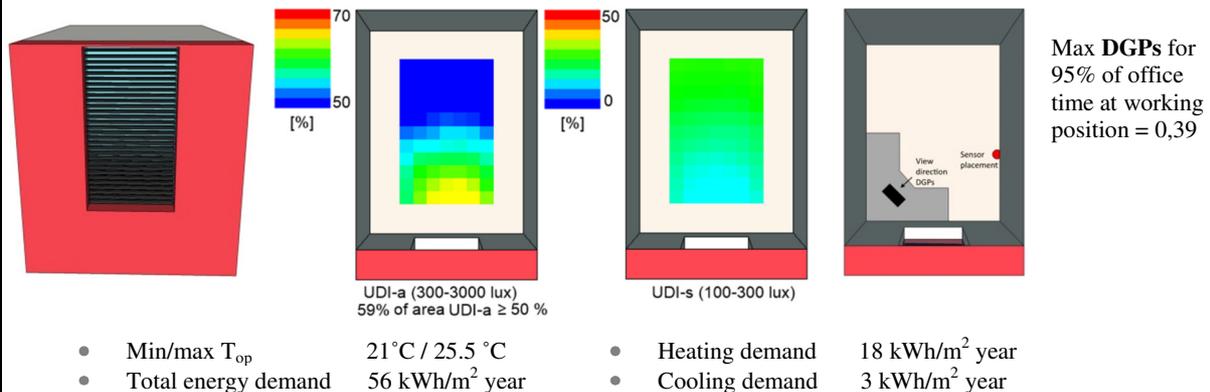
A simplified model of dynamic solar shading is used in the daylight calculation which block all direct sunlight and transmit 25% of the diffuse daylight.



The daylight does not satisfy the requireent completely. Yet, the simplified solar shading model might underestimate the daylight supply when closed and it will therefore be tested in if a more sophisticated solar shading might increase the area of satisfying daylight. If not, glazing characteristics or glazing area should be revised.

Detail design

It will be tested how a light grey external venetian blind system with a cut-off control strategy will influence the daylight, thermal comfort and the energy use. The solar shading is activated if external vertical irradiance $> 150 \text{ W/m}^2$ AND indoor air temperature $> 24.5^\circ\text{C}$ OR if vertical illuminance $> 2000 \text{ lux}$ at a sensor placed at the east wall behind the occupant work station at a height at 1.2 m. Since a cut-off strategy is used for the solar shading it is expected that peak glare sources will not be dominant and annual glare is evaluated according to DGPs.



Visual and thermal environment is satisfying and energy requirement fulfilled.

Discussion and conclusion

The literature reveals that a significant amount of research is conducted within the field of daylight during the last decades. To obtain an integrated design it is essential to use the same underlying calculation assumptions of climate data and control strategies for solar shading and lighting in thermal comfort, daylight and energy use analysis. Based on findings in the literature a proposal is given of how daylight evaluations may be implemented throughout the building design. The design proposal has been tested in design of a cellular office located in Oslo, Norway and the results shows that the methodology might lead to a design with satisfying visual and thermal environment and low energy use. It is expected that use of the method might have implications on design of facades and room layout since e.g. problems of glare in rooms with large glazed facades or problems with insufficient daylight illuminance in the core of deep rooms might be discovered in an early design stage and poorly designed proposals might be reconsidered. In order for the proposed design method to be practical applicable for building designers, it needs to be implemented in a user-friendly integrated simulation tool. Additionally, more studies are needed to confirm the suitability of UDI and DGPs/enhanced simplified DGP as a future annual daylight and glare metrics.

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Sustainability assessment of shopping centres

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Abstract: *The way we live is intimately connected with the way we buy. The supply of goods is linked to quality of life and needs a rethinking in order to be able meet the challenges of climate change mitigation. An analysis of existing European retail developments and their impact on local energy consumption is therefore needed. A cross methodological approach has been used including questionnaires that were sent to owners and managers, tenants and customers of shopping centres in 5 different countries in Europe, site visits and interviews. The assessment was done by applying the framework described in EN15643. The results of the questionnaires indicate a high interest concerning energy efficiency both on side of customers and tenants and their willingness to introduce e.g. energy efficient heating system, cooling system etc. All in all the developed methodology enables an assessment of shopping centres and possible refurbishment measures regarding sustainability.*

Assessment, KPI, sustainability, shopping

Introduction

The way we live is intimately connected with the way we buy. The supply of goods is linked to quality of life and needs a rethinking in order to be able meet the challenges of climate change mitigation. An analysis of existing European retail developments and their impact on local energy consumption is therefore needed. New procurement measures are necessary in order to be able to develop business models for the building and infrastructure industry that allows a cost effective transition of our built environment. In a larger research project which focuses on shopping centres, aspects regarding “sustainability” will be defined and analyzed taking into account buildings as social arenas, venues for experience, their interaction with the surrounding infrastructure, and their urban integration or interaction with the local built environment. These aspects are often described as “socio-cultural and functional aspects” within e.g. building certification schemes and methodologies that address the sustainability assessment of buildings. The goal was therefore to define such socio-cultural and functional aspects and to derive performance indicators to be analysed with respect to shopping centres.

Objectives

In this paper we seek for a definition and analysis of socio-cultural and functional aspects to be considered for shopping centres, including:

- (i) definition of typical shopping mall functional patterns
- (ii) analysis of the interactions between the stakeholders,

- (iii) studying inefficiencies related to the functional pattern,
- (iv) development of key performance indicators for energy efficient interaction in and operation of shopping mall.

Methodology

A cross methodological approach has been used including questionnaires that were sent to owners and managers, tenants and customers of shopping centres in 5 different countries in Europe (Eu-28 plus Norway), site visits and interviews. The assessment was done by applying the framework for the assessment of environmental, social and economic performance (EN15643).

In order to assess the energy inefficiencies in a systematic and transparent way the sustainability criteria and indicators developed in the EU FP7 research project OPEN HOUSE¹ (“Benchmarking and mainstreaming building sustainability in the EU based on transparency and openness (open source and availability) from model to implementation”) served as a structural basis. In a next step these sustainability criteria and indicators were investigated in terms of relation to energetic aspects. Therefore not only criteria with direct energetic context (e.g. energy needed for heating purpose in criteria “2.3 Thermal Comfort”) were followed up, but also criteria with indirect energetic context (see Image 1).

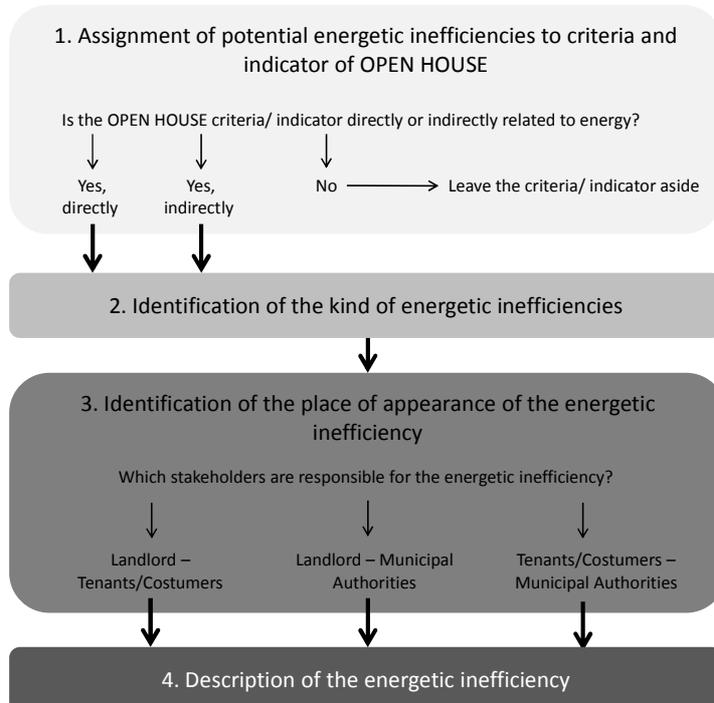


Image 1: Process of identifying possible energetic inefficiencies related to different sustainability criteria and indicators

Indirect energetic context can be the case if criteria specifying the use of specific equipment that needs energy in a second step (e.g. escalators in the criteria “2.1 Barrier-free

¹ <http://www.openhouse-fp7.eu/>



Accessibility”). In addition the term “energy” was not only understood as useable energy (e.g. electricity), but also as energy embodied in materials. After this the in literature (DGNB, 2012), (Grey, 2005), (Homolka, 2012), (Homolka, 2013), (Shhada, 2011), (Striebich, 2011), (Warrington, 2001) and by the help of experts identified potential energy inefficiencies were classified according to this criteria, set in relation to the place of appearance (e.g. field between tenant – landlord) and described into detail.

Results

Typical functional pattern can be defined as aspects establishing a framework to understand the activities within the shopping centre and its relationship with the surrounding environment both on a day to day basis as well as over the various time of the year. The definition of functional patterns helps in providing a basis for understanding of general use and the shopping centre as a social arena; it is not specifically related to energy efficiency or sustainability issues. To achieve a useful definition which may be used in relation to the majority of users involved in shopping centres it is suggested here that typical functional patterns for four main user groups should be defined. These are:

- customers
- tenants
- managers
- community

The stakeholders are influenced differently by the shopping centre: the customers are more interested in pleasant place and atmosphere, good shops, services and entertainment; they are also interested in comfortable indoor climate. Tenants and owners are more interested in reducing overheads and energy consumption. Their interests are more functional because management needs and their aim to achieve or improve profit margins. The needs of the four stakeholders influence the development, planning, design and location of shopping centres. Shopping entails different meanings for different consumer groups. Shoppers include all social groups and age ranges (Coleman). The functional patterns entail how to get the commodities as fast as possible, as smart and comfortable as possible or make use of shopping as a leisure activity. Shopping centres aim to encourage customers to spend more time in the shopping centres, and this is done by providing opportunities to do more than just shop. This is leading to improved architectural quality, with the creation of common spaces which are increasingly large and pleasant, and with introduction of more aesthetic elements which are not just about a more efficient business, but are intended to create a pleasant atmosphere (Malaspina, 2008).

Three of the four stakeholder groups were asked and answers are presented in Table 1. It can be seen that among the three stakeholders there is a large difference in range of importance when looking at inefficiencies in shopping centres. While customers rate the location, the wide range of products, the low prices and free car parking as most important, tenants answered customer satisfaction, Thermal comfort/indoor quality, worker satisfaction and cost

as most important. Managers of shopping centres rated reduced energy demand, customer satisfaction, architectural quality and improved orientation as most important.

Table 1: Excerpt from three questionnaires

Customers: What influences the choice of shopping centre?	Tenants: What do you see as most important when upgrading the SC?	Managers: What do you see as most important when upgrading the SC?
1. Location 2. A wide range of products 3. Low prices 4. Free car parking	1. Customer satisfaction 2. Thermal comfort/indoor quality 3. Worker satisfaction 4. Cost	1. Reduced energy demand 2. Customer satisfaction 3. Architectural quality 4. Improved orientation
15. Energy efficiency 16. Access to battery charging for electric cars 17. Architecture 18. Green building certificate	16. Green leases 17. Entertainment 18. Acoustic comfort 19. Improved orientation in the centre	16. Energy efficient storage and loading areas 17. more meeting places 18. more parking space 19. acoustic comfort

Table 1 also indicates the least important items. It shows that customers rated energy efficiency, access to battery charging for electric cars, architecture and green building certificate least important. Tenants rated Green leases, Entertainment, Acoustic comfort and Improved orientation in the centre least important while managers rated Energy efficient storage and loading areas, more meeting places, more parking space and acoustic comfort as least important. As a result of the previous described method for identifying energetic inefficiencies a list was set-up including sustainability criteria of buildings and potential energetic inefficiencies related to different stakeholder (see Image 2).

2.4 Indoor Air Quality
<p>Landlord – Tenants/Costumers: Tenants/costumers needs regarding indoor air quality are often not considered by landlords although it is very important for tenants/customers. => Over-/underestimation (e.g. open door policy vs. heating/cooling) and choice of inaccurate technical equipment => Ventilation rates are not defined by tenants</p> <p>Landlord – Municipal Authorities: Installations in shopping centers according to standards. => ventilation rates according to standards and not regarding local and regional characteristics</p> <p>Tenants/Costumers – Municipal Authorities: Tenants /costumers needs are not matching national or local standards and are therefore not considered (e.g. standard ventilation rates vs. ventilation rates adapted to CO2 level or number of persons).</p>

Image 2: Excerpt of the full list of potential energetic inefficiencies

Common findings of this analysis were that most of the energetic inefficiencies occur due to inefficient communication between the stakeholders and the installation of technical



equipment not attuned to the specific circumstances and needs but to general standard technical design, that includes high safety margins due to high uncertainties. As a potential solution a integral planning team including all stakeholders could be established in order to match design and actual needs. In addition the whole lifecycle of the building should be included in the planning in order to avoid shifting problems from production to operation or even End-of-Life.

The development of key performance indicators for energy efficient interaction in and operation of shopping malls came to the following elements:

- Project briefings

- project's intended approach
- guidelines which the design and construction teams will seek to implement in design
- strategies which the design and construction teams will seek to implement in design

- Integrated Planning

- Multidisciplinary formation of the planning team
 - A Sustainability Consultant
 - a Construction Manager or General Contractor with at least 3 more integrated project team members
 - at least 2 appropriate stakeholders (e.g representative of the owner and future users) in at least 3 phases of project design and construction process.
- Qualification of the Integrated Project Team
 - members in architectural and engineering chambers or other qualified chambers or associations
 - demonstrate further education with focus on sustainability.
- Design Charrette / Preparation of consultation
 - At least 2 full-day (resp. 4 half-day) or more workshops with the integrated project team
 - at least 3 appropriate stakeholders PLUS the owner/owner's representative
- Integrated planning process
 - Meetings with the integrated project team at least twice per month or more often
- Participation of future building users and other relevant stakeholders /Community impact consultation
 - Participation, consultative involvement, and a co-determination of the users and other relevant stakeholders took place.
 - The public were involved, informed and consulted, and they could participate

- Handover & Documentation

- Handover & Documentation



- Training on operating the building efficiently is given to BOTH technical staff (facilities managers) and non-technical end users, covering all environmental strategies (lighting, ventilation, heating and cooling)
- A plain-language, illustrated user manual is compiled, including recommendations and information for users to minimize ecological footprint, covering all environmental strategies (lighting, ventilation, heating and cooling)
- Detailed instructions for maintenance, inspection, operation, and care are compiled and a maintenance and repairs plan was drawn up; these instructions are specified for individual target groups (facility manager, etc.)
- **Building Performance Improvement**
 - The building has can evidence a reduction in energy and water consumption, and waste production over the years.
 - The building has achieved both ISO50001 and ISO14001
 - At least three organisations from the delivery team (architect, consultants, builders, subcontractors or client) can demonstrate that feedback from monitoring and evaluation has been communicated to their staff

The following energy related key performance indicators are the most used ones already:

- MJ Primary Energy Consumption (Operation)/ m²/year (if possible divided into heating/cooling/lighting/ etc.)

- MJ Primary Energy Non-renewable (Operation)/m²/year (if possible divided into heating/cooling/lighting/ etc.)

- average energy efficiency class of the building equipment

A key to successful application of the proposed key performance indicators is the use during the whole design process from project briefing to commissioning and beyond.

Conclusions

The evaluation of the questionnaires for customers, tenants and management/owner show some contradictory results. Therefore it is very difficult to take these into account concerning the aspect of energy inefficiencies.

Nevertheless the results of the questionnaires indicate a high interest concerning energy efficiency both on side of customers and tenants and their willingness to introduce e.g. energy efficient heating system, cooling system etc.

The development of key performance indicators for energy efficient interaction in and operation of shopping malls showed elements that need further analysis. A test of the key performance indicators in a real building project is planned for next year. This will give more information about applicability of the key performance indicators.



All in all, there are some social-cultural and functional aspects that can result in energy inefficiencies. Most of these aspects can be improved through good cooperation between landlords, tenants/ costumers and municipal authorities. Therefore already in early planning stages of refurbishment projects the important pre-studies have to be performed (economic studies related to kind of costumers and their expectations, energetic studies, studies regarding the infrastructure, etc.). These studies can serve as a basis for design and refurbishment decisions. The developed methodology enables an assessment of shopping centres and possible refurbishment measures regarding sustainability.

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Environmental renovation methodology in commercial buildings: the case of the Europa Palace in Vitoria-Gasteiz (Spain)

Speakers:

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Abstract: This article summarizes the first phase of the environmental assessment of the Convention Centre Europe (PEV-G) in Vitoria-Gasteiz (01), as a part of a wider renovation and expansion project. The Green Building Council Spain (GBCe) in collaboration with Societat Orgànica (SO) (02) proposed a methodology and actions for an ongoing process of environmental improvement for the building, analyzing its activities and the behavior of occupants and maintenance team, between January 2011 and September 2013. Through different models we have studied the existing building and the extension and renovation scenarios using the methodology of a simplified life cycle analysis and considering the environmental vectors energy, water, materials and waste. Options for improvement have been identified considering passive solutions, active solutions and management of the building, thus environmental objective were established. Finally, the requirements of the tender for final project and construction have been drafted, as well as an environmental protocol for the not yet executed phases. This protocol is valid for other buildings in Vitoria-Gasteiz, the Basque Country and all of Spain, to be renovated in the near future.

Renovation, refurbishment, methodology, LCA, energy efficiency

1. Project approach

The PEV-G (Figure 1) will be renovated and extended to reach an operational capacity of 2.5 times compared to the current. The conference and reunion south wing (on the right of the plan) will be refurbished without change of use, the north wing (on the left of the plan) will be renovated changing its use from sports into exhibition activities, and a large audience hall will be added to the center wing.

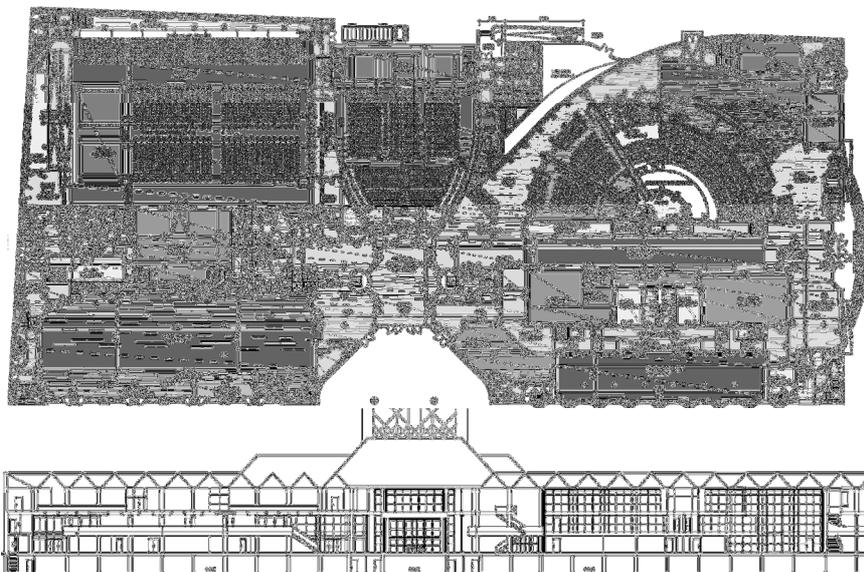


Figure 1. Ground floor and longitudinal section of Europa Palace Vitoria-Gasteiz



The complexity of developing a process of reducing environmental impacts throughout the renovation and extension of the building requires to consider how to interact with multiple factors: the deadlines set by the city council, the phases determined between them, the environmental work to be developed in each of these phases and the stakeholders involved before, during and after the process; all has to be integrated into a work plan (Figure 2).

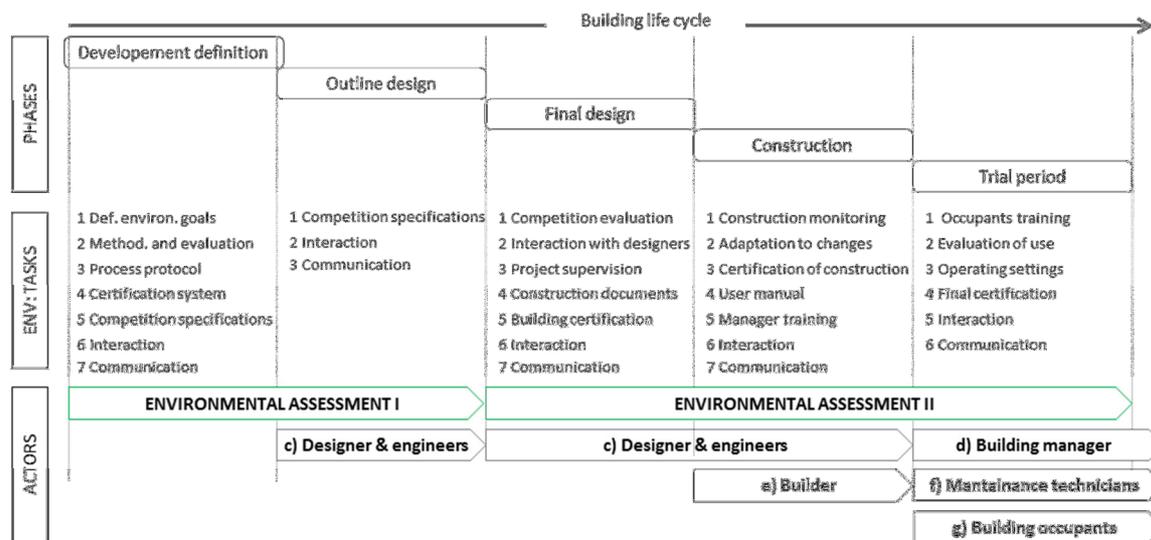


Figure 2. Working and tasks plan for the environmental renovation and extension of the PEV-G

Communication actions aimed at raising awareness of the transformation of the PEV-G in the community of Vitoria-Gasteiz, take place throughout the process, particularly on website (04).

2. Vision and environmental goals

The renovation and extension of the PEV-G had to define a strategy in order to obtain habitability and comfort at a reasonable cost of resources, maximizing the opportunities offered by the site, the building configuration, and its materials and several technical resources and facilities available. The work that has been carried out determined strategies and actions for the renovation, extension and operation that the PEV-G building had to implement in order to minimize its current environmental impacts and achieve the best possible standards of environmental quality considering the life cycle, and the energy efficiency in the operational phase. For this purpose it is intended to influence both the redesign of the building and its operation, as well as the integral management of the congress activity. In this regard, it is expected that the future offer of congresses and exhibitions of the PEV-G will be different from other regional alternatives because of its low ecological and/or carbon footprint (05) performing these operations, according to Vitoria-Gasteiz’s role as European Green Capital (06).

The following main environmental indicators have been used and will be used throughout the entire process: the consumption of energy, water and materials and the generation of solid waste and CO₂ emissions in a life cycle of 50 years, focusing especially in the renovation and extension phases and operation, being these the phases with the highest environmental impacts over the life cycle of the building (07). Environmental goals to be met along the

process of renovation, extension and building operation objectives have been defined: the building must achieve the highest level of the energy certification (RD 235/2013), at least 70% of the highest level in voluntary certification tools for environmental quality (VERDE-GBCe Tool and the Sustainable Building Guides IHOBE) and compliance with the prescriptive values of energy efficiency standard (PassivHaus, commercial buildings).

The content and sequence of the environmental work can be summarized as follows: a) defining a methodology for environmental renovation and extension of the PEV-G as a reference basis for other similar processes in other public and private buildings, b) the greening of specifications of the general process, competition and tender as well as drafting an environmental manual of building use and maintenance, c) establishing the current level of the environmental impact of the PEV-G and defining strategies and improvement actions to be applied in the renovation, extension and use, assessing their environmental and economic impact, d) determining the level of environmental impact of the building once reopened and compare with the objectives. Defining environmental requirements to be met in the planning stages, construction and commissioning, e) communication actions throughout the environmental consulting f) provide with environmental training the manager of the building, its technicians and users, so they can behave appropriately in the operational phase.

3. Methodology of analysis, improvement, tracking and certification

The methodology that would allow a comprehensive assessment of the environmental impact of buildings is the life cycle analysis (LCA) (08). However, its application in buildings is rare (09), due to its complexity. Addressing these problems and with the intention of creating a simplified methodology, but capable of performing a complete and replicable evaluation in other projects, a simplified LCA, useful for the assessment of trends of environmental impacts - not for highly accurate data – of the PEV-G, was implement. A simplified LCA permits a shorter completion time of the analysis', lower amounts of information to represent the life cycle and, eventually, lower economic costs because much of the work can be carried out with tools and information sources freely available or at least at a low cost (Figure 3).

	Material extraction and manufacturing	Use and building maintenance	Transport, construction and demolition
Energy (kWh/m ²)	Consumption of renovation and extension, considering the weight. Tools and dB: ITeC or Cype.	Demand, consumption and renewable en. HVAC and lighting. Tools: Enegy+, Ecotect, etc.	Estimates according to available sources (publications, research projects).
CO₂ (kg/m ²)	Consumption of renovation and extension, considering the weight. Tools and dB: ITeC or Cype.	Conversion of energy consumption into emissions according to official information in force	Conversion of energy consumption into emissions according to official information in force
Water (l/pers.)	Not considered	Consumption of network water and reuse by means of a water balance	Not considered
Waste (kg/m ²)	Not considered	Calculation of the production, dump and incinerator waste, statistical sources	Calculation of the production, dump and incinerator waste. Tools and dB: ITeC or Cype.

Figure 3. Table of impacts, life cycle phases and calculation tools

Using this simplified LCA, different constructive, HVAC and building management options, defined by considering the existing building and the preliminary design, were compared. The

work developed can be summarized as: 1) collection and study of building information. Plans, building systems, HVAC systems, consumption, use profile, climate, etc., 2) implementation of a computerized listing of its environmental impacts (energy, CO₂, water, waste, etc..) through its modeling, 3) determination of impact reduction options for renovation and use, with technical, economic and management assessment, 4) reprocessing computerized listing of the impacts of the proposed optimized building and verification of the compliance with environmental objectives 5) definition of performance (levels of consumption, emissions, etc., according to comfort and habitability conditions) and prescriptive (minimum quality of construction systems and facilities) requirements to comply. Drafting of the environmental specifications of the project and construction process.

4. Existing building evaluation

Once all available information about the building was collected and analyzed (plans, reports, usage statistics, usage profiles are facilities, visits, interviews with technicians, thermographic evaluation, etc...) the environmental vectors of energy, water, materials and waste of the building were modeled (Figure 5) in order to determine their current levels of impact, contrasting them with the regulatory requirements and benchmarks from other similar buildings and determining the causes of the greatest impact.

	Analysis conducted	Main problems detected
Energy and CO₂	Annual consumption according to sources HVAC and lighting consumption Efficiency of plants Solar control and natural lighting Thermography of envelope	Insufficient insulation and air-tightness, excess solar radiation through skylights, low efficiency and adaptability of HVAC, lack of air energy recovery, natural ventilation is not used, lack of comfort, control difficulties and building management contracting that discourages savings.
Water	Annual consumption of tap water Efficiency of plants Reusing rainwater Reuse of greywater	Inadequate segregation of consumption, lack of savings mechanisms, no greywater nor rainwater is reused and wastewater ends up straight to the sewer.
Materials	Impacts of existing construction Reusability potentials Impacts new construction	Constructive systems that hinder recycling, high-impact materials in some cases and constructive systems that need to be demolished to make when modifications have to be carried out
Waste	Generation renovation Generation in extension (nc)	In current practice there is a high waste generation, difficulties in the selective separation, reuse and recycling, and a high percentage ends up in dumps.

Figure 5: Evaluation of the existing building, analysis and diagnosis

In order to link the calculations of the environmental impacts to the operation of the building according to the actual real situation (last year) and future (prediction), a model that collects usage information and experience of building maintenance and operation was defined. This information includes parameters of the operation of spaces, schedules and days of operation, intensity and simultaneity in the use of spaces, comfort profiles and any other characteristics that could define the performance profiles of PEV-G. This is very important in the evaluation of the existing building, but also in the design of the renovation and extension project.

5. Improvement strategies and quality level to be reached

Several options for reducing environmental impacts have been analyzed, to be incorporated in the proposed renovation and extension of the building. Below (Figure 6), and following the

order of the environmental vectors considered, the major opportunities for improvement analyzed for the outline project (10), are presented.

	Analysis conducted	Opportunities
Energy and CO₂	HVAC and lighting consumption Solar control and natural lighting Alternatives for HVAC	Improving insulation and air-tightness of the envelope, solar control in skylights, change to more efficient HVAC and zoning, decreasing comfort requirements in areas of short permanence, energy recovery for fresh air, installing photovoltaic on the roof and cooling by natural ventilation.
Water	Efficiency of plants Reuse of water Natural purification	Savings mechanisms in south wings (renovation) and center (new construction), rainwater reuse, recovery of nutrients from wastewater, natural purification of greywater and natural discharge of treated water.
Materials	Low impact materials Potential for reuse and recycling	Maximum use of existing construction, renewable and recycled materials in renovation (south wing) and new construction (north side), building systems with mechanical joints for future reuse and recycling.
Waste	Decrease generation Potential for reuse and recycling	Minimize generation through the selection of constructive systems, increased selective separation through construction control, on-site reuse of aggregates and recycling of aggregate, metals, wood, plastics, etc...

Figure 6: Opportunities in environmental renovation and extension

Once the implementation of improvement opportunities are known, the following steps are to determine their economic viability, their practical implementation in the project, their influence on the use of the building and the training needed for operators and users.

6. Objectives of the Project, construction and operation

The outline design development and final definition of the construction budget can modify both the actions of environmental impact reduction as well as their effect on the final performance of the building. The legal framework regulating these aspects is the developed administrative and technical project and construction tender specifications. These documents, with the possible modifications carried out in the future, include the environmental protocol for the entire process, the requirements and methodology to be implemented in the verification of environmental objectives as well as the building operation analysis model. The environmental requirements enable the comparison of the existing building with the situation to be achieved once its renovation and extension is fully implemented. These requirements are organized both in performance terms, through quantitative verification (Fig. 7) as well as in prescriptive and methodological terms, to be implemented to the project and construction.

	Parameter	Existing building	Prediction of savings
Energy and CO₂	Demand	211 KWh/m ² year	52 %
	Consumption HVAC	158 KWh/m ² year	60 %
	Total consumption	240 KWh/m ² year	60 %
	Total primary energy	341 KWh/m ² year	63 %
	Total emissions	79 Kg/m ² year	60 %
Water	Total consumption	9 l/pers. day	80%
	Reuse	Not existent	Total in non-drinkable uses
Materials	Energy new construction	9.000 MJ/m ² approx.	50 %
	CO ₂ new construction t	1.000 Kg/m ² approx.	50%
	Renovationn energy	No reference	Demonstrably best alternative
	CO ₂ renovation	No reference	Demonstrably best alternative
Waste	Generation renovation	84 kg/m ² approx.	20%
	Generation in extension (nc)	No reference	Demonstrably max. reduction
	Non-recyclable	50% approx.	60 % (recycling el 80%)

Figure 7. Comparison of performance between existing and proposed building



Also following prescriptive requirements have been proposed: In energy, 30% reduction of thermal transmittance in building envelope, increased solar protection, condensation control, reduction of air permeability in joints and frames, elimination or reduction of thermal bridges and 40% of on-site produced renewable energy (compared to final electricity consumption), regardless of regulatory requirements (11). As for HVAC systems, higher efficiency in energy production, benefit from the passive criteria developed, free-cooling, flexible comfort conditions in some areas, increased distribution efficiency, reducing auxiliary energy consumption for pumping and ventilation, increased lighting performance in all power levels and regulation according to natural light and contracting a management service depending on the final efficiency.

In water, pressure reducers in the supply, low discharge WC (minimum 2/4 liters) with flow interruption, low flow faucets (3-5 l / min) and opening control, dry urinals, mechanical separation of the liquid and solid fractions in toilets and greywater natural purification and infiltration into the natural soil.

In materials, both for the renovation and for the extension, using a minimum of 20% recycled aggregate in concrete if structural and 100% in non-structural, minimum 90% recycled steel, constructive solutions that allow easy disassembly (dry joint) if the materials being joined do not have the same level of recyclability. In renovation the constructive solution has to be justified by the qualitative comparison of environmental impacts.

As for urban waste, designing spaces and facilities necessary for selective separation of at least the fractions of paper and cardboard, glass, plastic, metal, organic, specials, and other large recyclables, and an internal waste management that allows to adopt the external system of door to door collection.

	Requirements / Weighting	Additional improvements
Environmental objectives of design and construction	Good scores in energy certification, VERDE, IHOBE and PassivHaus performance. Performance objectives (quantification of impacts) and prescriptive (physical requirements) in energy, CO2, water, materials and waste	Highest levels in certification Overmatch performance and prescriptive objectives
Design and construction team	Demonstrable environ. & technical competence Proposal to meeting objectives Experience in similar projects with environmental requirements	Experts in additional disciplines Propose higher goals Experience or further recognitions
Builder company	Certification of environmental quality Demonstrable environ. & technical competence	Additional certifications Experts in additional disciplines
Tender score	A third dedicated to environmental aspects, built-in project literature
Environmental assessment team	Demonstrable environ. & technical competence Experience in similar projects Experience developing and managing certification tools	Experts in additional disciplines Superior experience
Project drafting	Environmental study with methodology of determining objectives	Improvements over the minimum objectives
Construction monitoring	Environmental plan with objective validation methodology	Improvements over the minimum objectives
Commissioning	One year of management by the builder, with verification of environmental objectives Warranty on value of contract	Overcoming environmental objectives during the first year of use

Fig. 12 Environmental aspects of the specifications of project and construction tender



7. Conclusions

The methodology based on a simplified LCA, tools and data freely available and the comparison between the baselines (the building itself, regulations, etc..) and the design project has allowed to adequately model the building, both in its present definition as well as proposed, and to establish environmental objectives and verification processes. It was essential to have a team that integrates the municipal officers of urbanism, environment, maintenance and building management together with the environmental consultants, with a common vision about what is sustainability, how to apply it in building and what actions are involved. Environmental impact savings that can be achieved in energy, CO₂, water and waste, according to current technical and economic possibilities, are between 20% and 80%. Preparing a building to operate with low environmental impact is not enough. Also an environmental work plan is necessary, from the decision to invest and develop up to the building operating, it implies specialists, managers and users, through training and information as well as carrying out routine monitoring and improvement. The methodology developed in this work, if adjusted to the characteristics of the buildings, climates and usage profiles, is applicable to many other cases in the city, the Basque Country and the rest of Spain.

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Session 83:

What should new envelopes for ZEB be like?

Chairperson:

Wassouf, Micheel

Director. Energiehaus scp

Primary energy implications of different external wall configurations for residential buildings

Abstract: *In this study, we investigate the influence of different external wall configurations on the production primary energy use of a residential apartment building in Sweden. The building is 4-storey with a wood frame external wall and rock wool insulation. Maintaining the same architectural design, we vary the external wall configuration from a wood frame to either a concrete frame or a brick façade/concrete frame with rock wool, glass wool, cellulose fiber or expanded polystyrene (EPS) insulation. We apply appropriate thicknesses of the various materials in the different external wall configurations, including that of the case study building to achieve similar overall external wall U-values, required to meet energy-efficiency standard of the Swedish building code of 2012 (BBR 2012). We then use a system analysis methodology to calculate the primary energy use for production of the building with the different wall configurations. We find that the timber frame wall system with cellulose fiber insulation results in the lowest primary energy use compared to the other wall systems in achieving the BBR 2012 energy-efficiency standard.*

Keywords: *Primary energy, external wall configuration, insulation, energy-efficiency standards*

Introduction

Residential and service sector buildings are responsible for about 40% of the total final energy use in the European Union [1]. Buildings are usually characterized by long life spans and high energy use for operation. Activities such as space heating, domestic tap water heating, ventilation and electricity for lighting and household appliances during the operating years of buildings contribute differently to the operation phase energy use and greenhouse gas emissions. For cold climates, energy required for space heating, especially in convectional buildings may account for a large part of the operation phase energy use. The application of stringent energy efficiency standards and construction of different types of low energy buildings are leading to significant reduction of building operation energy use but with possible trade-offs to other life cycle phases [2]. Stringent energy efficiency standards define building envelope thermal properties and specific energy use for building operation. These high energy efficiency standards may be attained with different building materials in varying quantities. Therefore, significant reductions in building operation energy use could be achieved, but the energy use for building material production may vary significantly with the choice of different building materials and improved energy efficiency levels. For instance, Thormak [3] studied the effects of different materials and recycling potential on the total production energy of a low-energy building and found that through material substitution, the production energy could increase or decrease by about 6% and 17%, respectively. Low-energy buildings are usually achieved through increased insulation application and thicker external walls. For multi-storey residential buildings, external walls are likely contribute significantly to the total building material production energy as they may constitute a large

portion of the overall building envelope area. It is important therefore to understand the primary energy implications of different building envelope materials in achieving improved building energy-efficiency levels. In this study, we analyse the primary energy use and CO₂ emission of a multi-storey residential building located in southern Sweden. We explore the influence of different external wall configurations with different insulation materials on the production primary energy use and CO₂ emission of the buildings.

Method

This study is based on a multi-storey wood frame apartment building with rock wool external wall insulation. We calculate and compare the primary energy use and CO₂ emission for the production of materials required for the buildings with different external wall configurations to achieve the energy efficiency level of the Swedish building code of 2012 (BBR 2012).

Studied building

The studied building is a multi-storey wood-frame apartment building constructed around 1995 in Växjö, Sweden to the Swedish building code of 1994 (BBR 1994) [4]. The building has 4 floors and 16 apartments with a total heated floor area of 1190 m². Two-thirds of the facade is plastered with stucco, while the facades of the stairwells and the window surrounds consist of wood paneling. A mechanical ventilation system for exhaust air is installed in the building. A photograph and floor plan of the building are shown in Figure 1.



Figure 1. Photograph (left) and ground floor plan of the studied building.

We modelled various changes to the studied building to achieve the requirements of the energy efficiency level of the BBR 2012 for non electric heated buildings in Sweden [4]. The changes include improved door and window U-values, improved external wall thermal characteristics, improved roof insulation and improved air tightness. The thermal envelope characteristics of the building to achieve the BBR 2012 standard are shown Table 1.

Table 1. Thermal properties of the improved building to the BBR 2012 standard.

Energy- efficiency standard	U-value (W/m ² K)					Air leakage at 50 Pa (1/s m ²)	Mechanical ventilation
	Ground floor	External walls	Windows	Doors	Roof		
BBR 2012	0.23	0.13	1.80	1.19	0.11	0.6	Exhaust air

External wall configuration

We vary the external wall configuration of the building from the initial wood frame with stucco plaster rendering to a concrete frame with stucco plaster rendering or a concrete frame with brick façade. We also vary the insulation material from the initial rock wool to glass wool, cellulose fiber or expanded polystyrene (EPS). We apply appropriate thicknesses of the various material components in the different external wall configurations of the studied building to achieve similar overall external wall U-values, required to meet the energy efficiency standard of the BBR 2012. As different thicknesses of the different external wall components are required to achieve similar thermal performances, the overall external wall thicknesses varied slightly. However, we assume that the floor areas and building volumes are adjusted accordingly to be identical among the different options of the building. Thus, it is only the external wall configurations of the buildings that differ for the buildings being compared.

Material production primary energy

We use the climate data for the city of Växjö in southern Sweden, where the studied building is located as input in the VIP+ simulation software [5] to analyse the annual final energy use of the buildings for space heating, domestic hot water and ventilation. All the buildings (with different external wall configurations) are modelled for the same final operation energy use according to the BBR 2012 energy efficiency standard, assuming indoor temperatures of 22 °C and 18 °C for the living and common areas of the buildings, respectively. We assume the buildings are connected to the district heating grid of Växjö. Based on the VIP+ models of the buildings, we account for all the materials required for the buildings. We consider the full materials and energy chain, including material losses as well as conversion and fuel cycle losses during the production processes and we calculate the primary energy used to extract, process, transport and assemble the materials required for the erection of each option of the buildings. We follow the methodology of Sathre [6] and use specific end-use energy for building materials production data from a Swedish study by Björklund and Tillman [7]. We did not account for the on-site construction energy used to assemble the building materials as we assume that this will not vary considerably for the functionally equivalent buildings. Based on Gustavsson and Sathre [8], we assume fuel cycle loss values of 10% for coal, 5% for oil and 5% for natural gas to convert end-use energy for material production to primary energy. We assumed that the electricity to produce the materials is generated in a coal-fired condensing plant with a conversion efficiency of 40% and a distribution loss of 2% [9].

Material production CO₂ emission

We calculate the CO₂ emission from fossil fuels required to extract, process, transport and assemble the materials for the construction of the buildings. For our calculation, we assume specific fuel-cycle carbon emissions of 18 kg C/GJ for natural gas, 22 kg C/GJ for oil and 30 kg C/GJ for coal based on [8].

Results

The primary energy use for the production of materials required to erect the buildings to achieve the BBR 2012 energy efficiency standard is shown in figure 2. The results show that the external wall configuration with wood frame plastered with stucco consistently gives the lowest primary energy use for material production required for the building to meet the BBR 2012 energy efficiency standard. This is followed by the concrete with stucco plaster and concrete with brick façade, respectively.

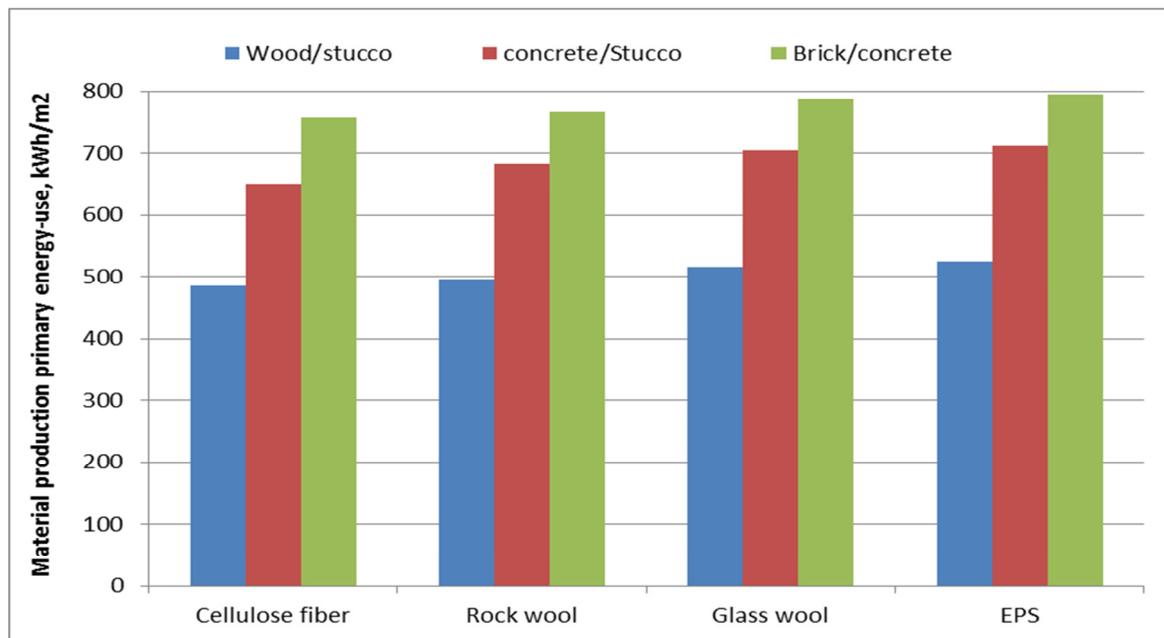


Figure 2. Materials production primary energy use of the buildings with different external wall configuration and insulation materials to achieve the BBR 2012 standard.

The material production primary energy use for the wood frame with cellulose fiber insulation was the lowest at 486 kWh/m² and this increases to 495, 516 and 524 kWh/m² for the wood frame with rock wool, glass wool and EPS insulations, respectively. The concrete with brick façade and EPS insulation gives the highest material production primary energy use of about 795 kWh/m² among the compared external wall configurations to achieve the BBR 2012 energy efficiency standard.

The corresponding CO₂ emission from the production of materials required to erect the buildings with the different external wall configurations to meet the BBR 2012 energy efficiency standard is shown in Figure 3. For the different insulation materials, the wood frame external wall configuration consistently gives the lowest CO₂ emission while the concrete with brick façade configuration gives the highest CO₂ emission. The wood frame configuration with cellulose fiber insulation gives the lowest CO₂ emission of about 46 kgCO₂/m² and the concrete with brick facade and glass wool insulation configuration gives the highest CO₂ emission of about 75 kgCO₂/m².

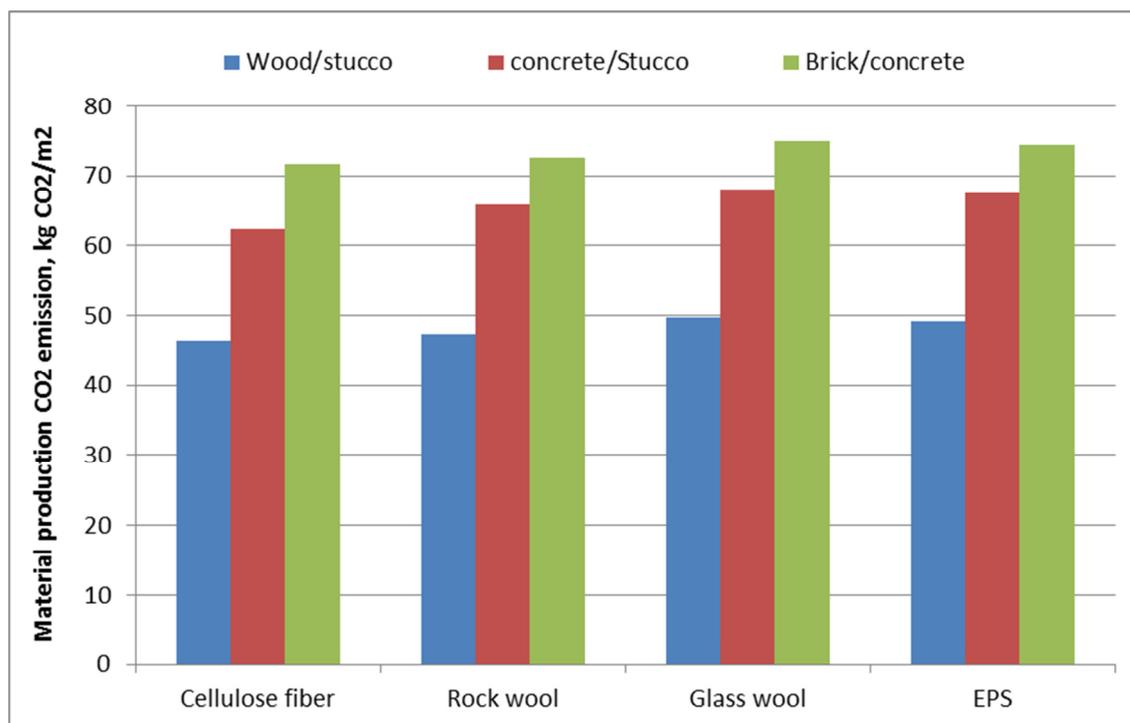


Figure 3. CO₂ emission from materials production of the buildings with different external wall configuration and insulation materials to achieve the BBR 2012 standard.

Discussion and conclusion

In this study we have explored the influence of different external wall configurations on the primary energy use for material production of a multi-storey residential building in Sweden. Our analysis is based on a modelled version of the building to meet the current Swedish building code of BBR 2012. We varied the external wall configuration of the building from a wood frame with stucco plaster to either a concrete frame with stucco plaster or a concrete frame with a brick façade. We also varied the insulation material of the different external walls from rock wool to glass wool, cellulose fiber or EPS. Our results show that the wood frame external wall configuration consistently gives the lowest primary energy use for material production with each of the considered insulation materials to meet the BBR 2012 energy efficiency standard, while the concrete and the concrete with brick façade options follow, respectively. Also, the wood frame with cellulose fiber insulation gives the lowest primary energy use for material production of about 486 kWh/m² as against the concrete with



brick façade and EPS insulation, which gives the highest primary energy use of about 795 kWh/m² (i.e. about 39% more). In terms of CO₂ emission from building material production for the different options of the building, the wood frame with stucco plastering still gives the lowest for each considered insulation material. This is followed by the concrete frame with stucco plastering and the concrete frame with brick façade, respectively. The wood frame with cellulose fiber insulation gives the lowest CO₂ emission of 46 kgCO₂/m² while the concrete with brick façade and glass wool insulation gives the highest CO₂ emission of 75 kgCO₂/m². The differences in primary energy use and CO₂ emissions of the external wall configurations analysed in this study may be due to varying factors such raw materials involved and their availability, material production processes and the energy supply systems, carbon content of the fuels used, among others.

Low-energy buildings are constructed to significantly reduce operation energy use but often this also leads to increase in energy for building material production. Therefore, it is important to consider the choice of materials used, especially in low-energy buildings to further achieve reduced primary energy use and CO₂ emission in the building sector.

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Carbon and Energy in Efficient Building Envelopes: A Comparative Case Study in Life Cycle Phases

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Abstract: *When buildings use very high-performing envelopes in order to reduce energy loads over the life of the building, it can be important to compare the environmental impacts in the manufacturing of the building envelope material with the lifetime environmental impact savings in building operations to avoid shifting the lifecycle environmental burden from the use phase to the construction phase. In this paper, we use a pair of case study buildings to offer a model for using life cycle assessment to compare the additional embodied carbon and energy in a high-performance building to the life cycle carbon and energy savings in its improved performance.*

In this case study, the two subject buildings are identical multifamily housing blocks except that one is designed to the U.S. Passive House (PH) standard and one is designed to the regional Earth Advantage energy standard. In comparing the additional materials required to achieve the very ambitious Passive House energy standard with the resulting net use-phase savings, we found that there are significant environmental impacts associated with the additional construction materials for a PH upgrade but also that these impacts would be offset by the increased building efficiency. The study also shows the degree to which the energy grid mix and material choice impact the carbon and energy “payback time” for the improved envelope.

Key words: *life cycle, embodied carbon, life cycle assessment, passive house, multifamily housing*

Life Cycle Phases in High Efficiency Buildings

In the context of very low operations energy buildings such as those built to Net Zero or Passive House standards, it is important to ensure that the impacts embodied in the improved building construction do not exceed the impact savings of the operations phase. The strength of life cycle assessment (LCA) as a method for quantifying the environmental impacts of buildings is its capacity to include and compare the embodied impacts in the construction of a building with the impact of its operations over the building’s lifetime. An LCA approach to evaluation can ensure that the environmental cost of improved building construction (such as increased insulation) can be “paid back” through increased building efficiency instead of inadvertently shifting the environmental burden from the use phase to the construction phase with no overall environmental savings over the lifetime of the building.

In energy efficient buildings in which better design and construction is meant to reduce operations energy, the proportion of energy (and so greenhouse gas emissions and generally other environmental impacts) embodied in building materials can be high. In some cases, the environmental burden of the use phase could be inadvertently shifted to the materials themselves at no overall environmental benefit. In this context, LCA offers an appropriate model for analyzing the long-term environmental impacts of design decisions.



This study uses a life cycle assessment model to compare the difference between the full lifespan environmental impacts of a multi-family housing project built to the Earth Advantage energy standard, a regional standard for some increased efficiency, with the same project built to the U.S. Passive House standard. While the use-phase energy of a project built to the Passive House standard is by definition extremely low, in this study we ask: What additional materials in the building’s envelope are needed to achieve that energy efficiency and what are the environmental impacts associated with those materials? Is there a net improvement in full lifecycle environmental impacts with the U.S. Passive House upgrade?

This study is meant to primarily estimate greenhouse gas (GHG) emissions and non-renewable energy use, as energy use and climate change are the two most publicly recognizable impact categories. We also look at a handful of other impact categories, including acidification, carcinogenic and non-carcinogenic toxins to humans, respiratory effects, eutrophication, ozone depletion, ecotoxicity, and smog.

Project Goal

This study is intended to contribute to ongoing research on the environmental context of Passive House building design in the US and to the field of whole-building lifecycle assessment. The study results will also be made available to Stellar Apartment project team members and developers for use in their building planning.

Methodology

In this study we estimate the net change in total environmental impacts in upgrading an Earth Advantage energy standard apartment building to the Passive House energy standard, including additional impacts from the increased building materials and reduced impacts from the improved building efficiency over the course of the building’s lifespan. The ‘upgrade’ here, it should be clear, refers to changes during the design phase in order to make the new design meet the PH standard. It does not refer to physical alterations to an existing building.

To estimate the change in environmental impacts associated with the building materials, we subtracted the impacts associated with the materials removed in the upgrade from the impacts associated with the materials added in the upgrade. To estimate the difference in the environmental impacts associated with the building’s operations, we subtracted the impacts of the estimated Passive House operations energy over the projected 60 year lifespan of the building from the impacts of the estimated baseline Earth Advantage operations energy. The net change in total environmental impacts in the upgrade from Earth Advantage to Passive House energy standards is the difference between the change in impacts from the materials and the change in impacts from the building’s operations (figure 1).

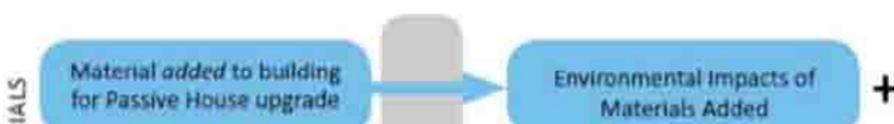


Fig. 1: Net change in total environmental impacts

Case Study Comparison

We are comparing two different versions of otherwise identical 5,000 ft², 3 story apartment buildings with 6 living units in terms of the materials in their building envelopes and mechanical systems and their estimated operations energy. The case study's baseline apartment building meets Earth Advantage energy standard. The Earth Advantage Homes Multifamily certification process includes prescriptive and performance-based components. Projects must be modeled to show a 10% increase in operational energy performance beyond code. For the Passive House standard, buildings must have an air-tight building shell measured by a blower-door test and an annual heating requirement of less than 4.75 kBtu/sf-yr and an annual Primary Energy Demand (total energy consumed including inefficiencies in production and transmission) of 38.1 kBtu/sf-yr. Figure 2 shows the materials removed and the materials added in the upgrade of the case study building to the Passive House standard.

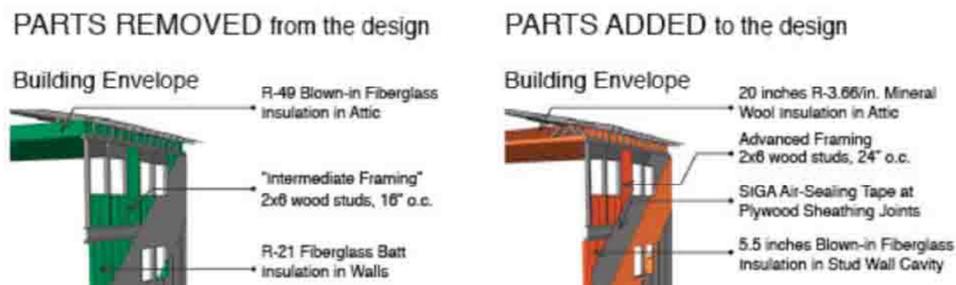




Fig. 2: Materials removed and materials added in the upgrade of the case study building

Project Scope and Assumptions

Because this project is meant to study the differences in environmental impacts between the two case study versions but not the total impacts of either project, the study boundaries are very narrow. We include impacts of the materials added to (and removed from) the case study to meet the Passive House standard but do not include the rest of the building that does not change. We account for the manufacturing of the building materials but not for their transportation to the site or their installation. We do include a factor for the replacement of these building materials over the projects' life spans and a factor for material waste during construction.

For both versions of the case study we assume a 60-year service life, in line with what little research exists on residential building service lives in the United States. We also understand that this assumption is relatively arbitrary since the actual lifespan of a building is subject to many unpredictable factors including land redevelopment, natural disaster, and wear.

For the materials impacts, we modeled the impacts inventory on the 2010 study completed by the Oregon Department of Environmental Quality, "A Life Cycle Approach to Prioritizing Methods of Preventing Waste from the Residential Construction Sector in the State of Oregon."

For this study, we focus on two key environmental impact categories to estimate the impacts of the building upgrade: non-renewable energy, measured in megajoules (MJ) and gigajoules (GJ), and GHG emissions, measured in kilograms (kg) and metric tons (MT) of CO₂ equivalents (CO₂e.)

To calculate operations impacts, we assign an energy use intensity (EUI) to each version (baseline EA and upgraded PH) of the case study's on-site energy used per square foot of floor area per year. For the Passive House version of the case study, we assume an EUI of



14.1 kBtu/sf-yr. This is based on the certification requirement for the Passive House standard, which dictates a maximum Primary Energy Demand (energy consumed at the power source) for a building and an efficiency factor that translates primary energy to energy used at the building.

While the Passive House standard prescribes maximum operations energy, an EUI study value for the baseline Earth Advantage version of the case study is more difficult to establish since that standard simply requires a 10% improvement over code. For the purposes of this study we assume an EUI for the Earth Advantage version of 40 kBtu/sf-yr, a “best guess” that we established by comparing this project to several comparable projects modeled by SOLARC Architecture & Engineering. Because this assumption is impossible to validate during the design phase and because this assumption is very significant to our study, we include alternate values for a baseline Earth Advantage EUI in our findings.

The way that we model the electricity grid mix is also significant. For our primary results, we chose to model a grid mix that represents that of the northwest region of the United States, the Northwest Power Pool (NWPP). If we were to assume a national average grid mix that includes a higher proportion of coal-generated electricity, then there would be higher impacts associated with the operations of the case study buildings. If we assume our local grid mix from the Eugene Water and Electric Board (EWEB) of primarily renewable energy sources like hydro and wind power, there would be smaller associated impacts. Because of the significance of this factor in our study, we also include results for local and national grid mixes in our findings.

Findings

Given our study assumptions, we estimate that the total difference in life cycle environmental impacts in the upgrade from Earth Advantage to Passive House energy standards can be measured in a savings of about 13,000 GJ of nonrenewable energy and 987 MT CO₂e in GHG emissions. Based on this estimate, we can infer that the environmental costs of the additional construction for the upgrade would be “paid back” in 1.6 years for nonrenewable energy and 1.4 years for GHG emissions.

There is some variation in results among the other impact categories studied. Acidification (measured in H⁺ moles eq), ozone depletion (measured in kg CFC-11 eq), and smog (measured in g NO_x eq) all are similar to the results described above, in that the operational savings far outweigh the initial material impacts, by a factor of at least 9, and as much as 21. Carcinogenic toxins (measured in kg benzen eq), respiratory effects (measured in kg PM_{2.5} eq), and ecotoxicity (measured in kg 2,4-D eq), show a clear net benefit as a result of the upgrade, though not as dramatic as the impacts already listed. For these the operational savings outweigh initial material impacts by factors between 2 and 5. Impacts from the upgrade of eutrophication (measured in kg N eq), and non-carcinogenic human toxins (measured in kg toluen eq) are close to net-neutral.



The two most significant variables in determining upgrade payback time in our study model are the EUI we assign to the Earth Advantage version of the case study building and the way we define the electricity grid mix. If, as an alternative, we assumed a very inefficient case study building as in the 75 kBtu/sf-yr that the EPA Target Finder assigns to multifamily housing and if we assume a national energy grid mix that includes more coal power, we can estimate a payback time for the upgrade of only 0.3 years for nonrenewable energy and 0.4 years for GHG emissions. At the same time, if we assume a somewhat more efficient Earth Advantage building with an EUI of 33 kBtu/sf-yr with electricity just from EWEB, the payback time in non-renewable energy would be 5.7 years and the payback time for GHG emissions would be 14.9 years (figure 3).

It is also important to note that our case study upgrade assumes rigid polyisocyanurate foam for exterior wall insulation. Polyisocyanurate is relatively benign in terms of GHG emissions in its production, and if that were replaced with equivalent amounts of extruded polystyrene (XPS), a foam that is much more GHG-intensive in its production in the U.S., the modeled payback time for GHG emissions would increase to 48 years, approaching the estimated lifespan of the building.

Implications

This study confirms that in terms of total life cycle nonrenewable energy consumption, GHG emissions, and several other environmental impact categories, the upgrade of this apartment building from the Earth Advantage to the Passive House Energy standard would be well worth the environmental cost of the additional construction materials. Our study of alternative EUI values for the Earth Advantage case study and for alternative grid mixes shows just how environmentally significant such an upgrade could be for regions with high emissions electricity production and poor energy codes. The study also shows diminishing returns for regions that have fewer emissions associated with their electrical production or in cases when additional building materials have a high proportion of GHG emissions associated with their manufacture.

When we break down the environmental impacts of the materials added and removed in the upgrade, it is clear that while there are incremental differences in other materials, the largest additional impact in materials comes from the two types of additional insulation. In this case this is the mineral wool attic insulation and the polyisocyanurate wall insulation.

Broader Implications

While the results of this research are tied to the particular circumstances of this case study, the study results can help to fill in a larger picture of the relationship between improved building efficiency and the environmental impacts of the additional materials to make a building more efficient. The study offers a model for using life cycle assessment to predict manufacturing and construction phase impacts.

While in most cases it is probably a very good decision to improve a building envelope, building designers and developers should consider the possibility of no net benefit in terms of

total life cycle environmental impacts with an improved building envelope. To avoid this rare circumstance, particular attention should be paid to the global warming potential of insulation materials and the relative emissions of the operations energy sources.

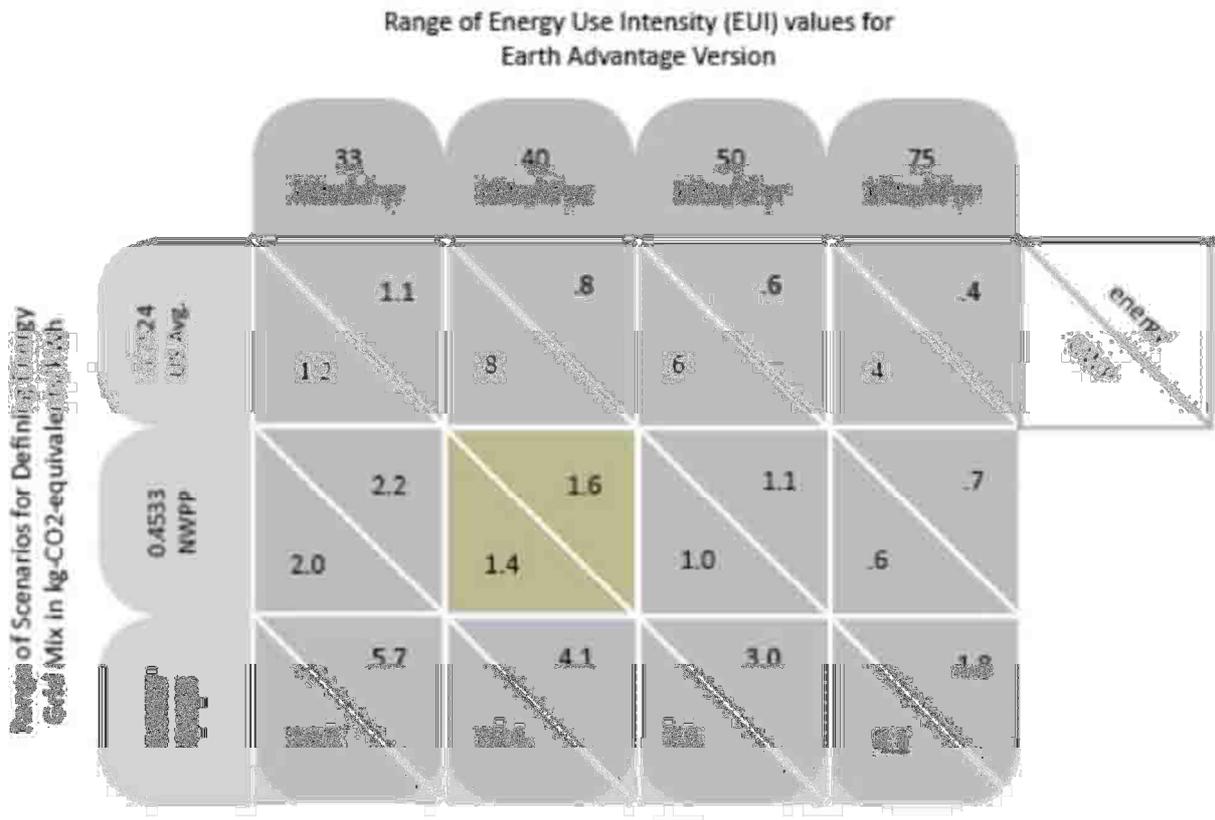


Fig. 3 Variables in environmental payback time in years for energy and global warming potential

Limitations of Study

It should be noted that this study does not aim to draw general conclusions about the relative lifecycle environmental impacts of Passive House buildings. As this study is region-specific, there is a particular utility grid mix, as described above. In addition, the types and quantities of materials used to attain the Passive House standard cannot be generalized. Other climatic regions will require different amounts of materials and different types of construction. The Passive House standard does not prescribe construction types or materials, only benchmark performance standards, so even within the region of the case study, there are many different configurations of materials and assemblies that could be used to achieve the standard on the case study building. Different material choices would lead to different outcomes in terms of embodied environmental impacts.

It should also be noted that while the methodology used here is sufficient to address the question of lifecycle environmental impacts associated with a building upgrade to the Passive House energy standard, it does not estimate the building’s total lifecycle environmental



impacts. As the trend continues towards buildings with lower operational energy needs, it will be important to determine what portion of their overall associated environmental impacts can be attributed to materials and what portion to operations. Especially in regions of relatively clean energy production, this will help to determine where design interventions will be most effective in terms of reducing overall lifecycle impacts.

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Assessment and selection of external walls of buildings based on their environmental performance “from cradle-to-cradle”

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Abstract: *This paper presents the evaluation of external walls of buildings by assessing their “cradle-to-cradle” (C2C) environmental performance in accordance with recent European standards. Each solution was assessed mainly using site-specific data for each component and considering its location in a building in Portugal. A supplementary approach was used to quantify each environmental aspect on an economic unit. Quantified results for the environmental performance C2C (without weighting or aggregation) in six environmental categories is presented for the first time for the 60 alternatives evaluated, along with an analysis of the contribution of each life cycle stage to the C2C environmental costs of each external wall.*

Keywords: *cradle to cradle, energy performance, environmental impact, external walls, life cycle assessment (LCA).*

Introduction

Building designers are increasingly concerned with finding sustainable building materials and assemblies to include in their projects. However, to become “sustainable”, the construction sector needs scientific-based tools that allow measuring the “real” sustainability of each project. These tools must also aid the process of selection of building assemblies that maximise the environmental sustainability of a building, from the various alternatives available on the market. This paper presents the evaluation of alternatives for the external walls of buildings through the assessment of their environmental life cycle from cradle to cradle (C2C) in accordance with recent European standards.

Method - Assessment of the environmental performance

The quantification of the environmental performance C2C of each wall follows the Life Cycle Assessment (LCA) standard method (ISO 14040:2006 and 14044:2006), and includes eight impact categories (using CML 2001 baseline - version 2.05) and the life cycles stages described in Table 1. Most of the principles already included in standards EN 15643-2:2011 and EN 15978:2011 were also followed, namely:

- The results of the assessments shall be organized in three main groups (Table 1): impacts specific to building fabric and site (results from the product stage and from the construction process stage - A1-A4), impacts and aspects specific to the building in operation (maintenance, repair and replacement, and energy use for heating and cooling - B2-B4, and B6) and results from the end-of-life stage of the building (C2-C4 and D);



- The quantification of the impacts of operational energy (B6 sub-stage) is a direct result of the calculation of the energy used during the use stage according to the EPBD (Directive 2002/91/EC) and shall be derived from different energy carriers or LCA databases;
- The impacts and aspects related with benefits and loads beyond the building life cycle, e.g. those that result from further reuse, recycling potential and energy recovery and other recovery operations, are also included as supplementary information (D stage);
- The default value for the reference study period shall be the required service life of the building and the estimated service life of the assemblies shall take into account rules and guidance included in the standards ISO 15686-1,-2,-7 and -8.

Each external wall solution was assessed mainly using data from studies made in national plants for each component (12 out of 16: six thermal insulation materials, two elements of the wall structure, five external claddings and three internal coatings) for the Product stage (A1-A3) performed using SimaPro software, and considering its location in a building in Portugal. For the remaining materials, the NativeLCA methodology was applied in the selection of LCA data sets to be used as generic in the Portuguese context.

The Construction process stage (A4-A5) includes the environmental impacts of (EN 15804:2012): the transportation from the production gate to the construction site (A4); the on-site storage of products, the waste of construction products and the processing of product packaging and product waste (A4-A5); and the installation of the product in the building (A5). The energy and water required for installation or operation of the construction site were not considered due to their variable and unpredictable nature.

The use stage (maintenance, repair and replacement - B2-B4) concerns the quantification of the environmental impacts of the materials used in maintenance, repair and replacement operations over the life cycle of the assembly (in the year that they occur). To estimate the environmental impacts of the consumption of energy for heating and cooling (B6), the energy needs of the flat (in kWh) by year of the study period were divided by the area of the external wall (40.27 m²) to yield a value related to the declared unit. This value (in kWh), times the years of the study period, was inputted in SimaPro and the environmental impacts were calculated considering a process to model the domestic consumption for heating/cooling that represents an updated Portuguese electricity mix (data from 2011).

For the calculation of the environmental impacts of the End-of-life stage (C) and of the Benefits and loads beyond the system boundary (D), deconstruction was considered, including the transporting and disposal of Construction and Demolition Waste (CDW) in suitable sites. The environmental impacts of transporting and disposal of the CDW generated were based on Portuguese case studies that used waste operators data.

A complementary approach was used to quantify each aspect of the assembly's environmental performance using the same unit. This approach uses an environmental impact assessment method (EIAM) with a weighting step that converts the results of all LCA impact categories into an economic unit, resulting in an overall single score. This EIAM - *Eco-costs 2007* - is a prevention-based single indicator for environmental burdens, whose economic unit is the Euro [1]. *Cev* corresponds to the application of the EIAM *Eco-costs* to the LCA results for each life



cycle stage. Table 2 presents a comparison between the eight environmental impact categories of CML 2001 baseline and all the *Eco-costs* impact categories (the ones used in the single indicator determination), where the related categories are placed in the same line, and the weighting factor defined in *Eco-costs* for each environmental impact category. Table 2 shows that the *Eco-costs* indicator includes environmental categories that are similar to those most often used in the environmental assessment of construction materials and assemblies. The characterisation tables of *Eco-costs* for acidification, eutrophication and summer smog (photochemical oxidation) are even equal to those from CML 2001. *Eco-costs* includes also toxicity impact categories (i.e. aquatic ecotoxicity, fine dust (PM 2.5) and carcinogens) which, despite also being included in CML 2001, are not usually used in LCA studies because of their high uncertainty and lack of scientific robustness ([2] cited by [3]). Due to this fact, these impact categories were not considered in this approach. The ozone layer depletion category is not considered in *Eco-costs* because HCFCs are already banned in Europe and in the USA [1]. Nevertheless, these gases are considered in the global warming potential characterisation tables of this EIAM. As for the waste produced in the system process under study, *Eco-costs* gives economic credits to recyclable or combustible waste and considers the cost of disposal of inert or mixed waste (i.e. non-recyclable and non-combustible). This impact category is not considered in this approach to avoid double counting. In fact, since all assemblies are modelled in detail from C2C using LCA software, an appropriate end-of-life (e.g. recycling or landfill) is attributed to each waste flow, according to the Portuguese situation, and the emissions and avoided burdens of these waste flows are duly quantified and assigned to the corresponding module (e.g. to Module D - Benefits and loads beyond the system boundary).

Scope - system boundaries, declared unit and case study

The assessment is made from cradle-to-cradle, including the life cycle stages of construction products already standardised (Table 1- including the extraction and processing of raw materials and the production, the transportation, distribution and assembly, use, maintenance and final disposal (EN 15978:2011 and EN 15804:2012). This approach includes therefore the life cycle stages and/or processes affected by the external walls (i.e. material production and transport, heating and cooling, and maintenance operations), but does not include the environmental impacts of activities during the use stage not dependent on the exterior wall solution.

The declared unit was defined as ‘a square meter of external wall for 50 years’, taking into account the use and end-of-life stages and the reference service life of each alternative. A declared unit, instead of a functional equivalent (EN 15804:2012), allows the designer to compare two or more assemblies to select the best one, even if they are not functionally equivalent (e.g. external walls with different heat transfer coefficients).

The model building has five residential floors and represents the most common constructive and architectural practices in Portugal. The subject of the study is the flat on the right from an intermediate floor with no building next to the east façade (Figure 1). The location chosen



was Lisbon, the national metropolitan area with the highest building density. The external walls studied are on the north and south façades (the east façade is considered to be the same for all alternatives). The reference study period was set at 50 years. 60 external wall solutions were evaluated, including single-leaf walls with internal or external insulation, and cavity walls. Table 3 shows a summarised characterisation of the outer wall alternatives.

Results and discussion

Environmental performance C2C (without weighting or aggregation) in six environmental categories are presented in Table 4 for alternative W1, and in Table 5 for the remaining 59 external wall solutions being evaluated in terms of difference in percentage for W1. These results do not include B6 sub-stage (energy use for heating and cooling), because it is directly related with the U-value of each alternative and therefore stems directly from the energy needs of the flat and do not help as a standalone criterion in the choice of the best environmental performance solution [4]. However, the relationship between the U-value and the energy use for heating and cooling is not the same for each group of alternatives since it depends on the relative location of the insulation.

An overview of the LCA of the 60 alternatives allows concluding that:

- Single leaf walls with GFRC panels as external cladding (W21 and W22) present the worst performance in five out of six categories (except EP), despite having the lowest heating and cooling needs within the alternatives being evaluated;
- In EP, the worst performance corresponds to single leaf walls with wood-plastic extruded boards as external cladding (W11 to W20), namely W18;
- The best overall environmental performance in three categories (ADP, EP and POCP) correspond to the cavity wall with a painted cement render as external and internal cladding and LWA filling the whole cavity (W37). This better performance is however offset by the worst thermal performance of this solution (along with W38, W39 and W40) in comparison with the remaining alternatives evaluated;
- The best performance in the remaining categories corresponds to the single leaf walls with a painted cement render as external cladding and gypsum plasterboard glued over the internal insulation (W28 to W31), namely in: AP (W28, with an EPS board); GWP (W29, with an ICB board); and in ODP (W31, with a XPS board).

Figure 2 and Figure 3 present the NPV (net present value [4]) of the environmental cost (Cev) C2C of the 60 alternatives, and lead to the following conclusions about the contribution of each life cycle stage:

- The production (A1-A3) of each wall can represent between 31% and 56% of its discounted C2C environmental cost;
- The environmental cost of the transport to site (A4) varies between 1.1% and 2.2% in the NPV of the Cev C2C of the alternatives evaluated;
- The process of installation in the building (A5) represents a maximum of 5.9% of the C2C environmental cost of an external wall, but, on the other hand, can contribute up to -1.6% of the environmental cost (or 1.6% of the environmental benefits) in other alternatives;
- The discounted environmental cost of the maintenance operations (B2-B4) can signify between 0.7% and 7.5% of the C2C impacts of an external wall;
- Concerning the environmental costs of energy use (B6), its discounted value can contribute between 36% and 65% to the C2C impacts of each alternative, and the external walls that present these values are the same with extreme values for the product stage (A1-A3), but in inverse order;



- The discounted end-of-life stage (C2-C4, and D) environmental cost can represent 0.4% of the C2C environmental cost of an external wall as a maximum, but, on the other hand, can contribute up to -1.4% of the environmental cost (or 1.4% of the environmental benefits) in other alternatives.

An overview of the NPV of the environmental cost (Cev) C2C of the 60 alternatives shows that:

- Single leaf walls with GFRC panel as external cladding and gypsum plasterboard as internal cladding (W22) have the highest NPV of the environmental cost (Cev) C2C and also the worst performance in the product stage (A1-A3), which agrees with the analysis made of the LCA results C2C. The best performance at this stage is also achieved by single leaf walls but with a painted cement render as external cladding and gypsum plasterboard glued over an ICB board (W29);
- The solution with the lowest environmental cost from a C2C perspective is W3, which is a single leaf wall with external insulation, an ETICS system with an ICB board as external cladding, and a painted cement render as internal cladding;
- Single leaf walls with external insulation with extreme environmental cost at the use stage (B2-B4) are also the ones with the highest (W11 to W20, with wood-plastic extruded boards as external cladding) and lowest (W21 and W22, with GFRC panels as external cladding) maintenance costs.

Conclusion

This paper presents the application of a method to aid in the choice of an external wall alternative for a building based on the assessment of their environmental life cycle from cradle to cradle in accordance with the most recent European standards. The method proved useful for: comparing solutions that comply with all the requirements but that are not functionally equivalent, without the need of changing their characteristics to make them comparable; quantifying the environmental performance of the alternatives in each stage of their life cycle, and also from cradle to cradle. A supplementary approach was also used that establishes weights for each aspect of the environmental performance of the assembly and for their quantification using the same unit, therefore preventing contradictory conclusions that can arise from the individual analysis of each environmental category.

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Notes to Table 3: External cladding systems (ECS): ECS1 - Adherent (0.02 m render and water-based paint); ECS2 - One-coat mortar; ECS3 - Adherent [0.02 m render, adhesive, (insulation), glass fibre mesh, 0.01 m render and water-based paint] within an ETICS (External Thermal Insulation Composite System); ECS4 - Fastened to a supporting structure - VRF (Ventilated Rainscreen Façades - 0.02 m render in the outer surface of the CHB, and WPC (Wood-plastic composite) structure and boards creating a ventilated cavity); ECS5 - GFRC (Glass Fibre Reinforced Concrete) precast panels with 12 cm EPS boards as void formers; Internal cladding systems (ICS): ICS1 - see ECS1; ICS2 - Adherent to the wall structure (adhesive, gypsum plasterboards and water-based paint); ICS3 - Adherent to the insulation material [adhesive, (insulation), gypsum plasterboards and water-based paint]; Insulation materials (the number is the thickness in cm) - EPS (Expanded Polystyrene), ICB (Insulation Cork Board), LWA (Light Expanded Clay Aggregate), PUR (Polyurethane), SW (Stone wool) and XPS (Extruded Polystyrene); Elements of the wall structure (plus stabilised masonry mortar; the number is the thickness in cm) - CHB (Hollow fired-clay bricks, horizontally perforated), LCB (Lightweight - with LWA - concrete blocks, vertically perforated), and CHB 15+11 (cavity wall, plus internal 0.02 m render).

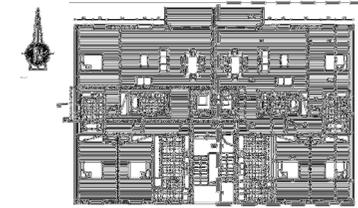


Figure 1 - Model building called Hexa - design drawing of a middle floor: the subject of the study is the flat on the right, with no building next to the east façade

Table 4 - LCA results for wall W1

External wall solution	ADP	AP	EP	GWP	ODP	POCP
	kg Sb eq	kg SO ₂ eq	kg PO ₄ ³⁻ eq	kg CO ₂ eq	kg CFC-11 eq	kg C ₂ H ₄ eq
W1	4.16E-01	3.01E-01	5.02E-02	7.75E+01	8.67E-06	3.64E-03

Table 5 - Difference from W1 (%) of LCA C2C results (A1-A5; B2-B4; C2-C4 and D) for single leaf walls with external, internal (W27-W36), and without (W23-W26), insulation, and for cavity walls (37-W60)

CML 2001 baseline category (Unit)	External wall																												
	W									W1									W2										
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
ADP (kg Sb eq)	0	-44	-56	-39	-35	6	-38	-50	-33	-29	24	-21	-33	-15	-11	30	-15	-27	-9	-5	91	97	46	52	50	56	-2	-47	-59
AP (kg SO ₂ eq)	0	-12	6	-8	-3	-2	-14	4	-10	-5	24	12	30	16	21	22	10	28	14	19	84	82	64	62	68	66	-8	-20	-2
EP (kg PO ₄ ³⁻ eq)	0	-24	73	-34	-5	2	-22	76	-32	-3	563	539	636	529	558	565	541	638	531	560	139	141	4	6	11	13	-7	-31	66
GWP (kg CO ₂ eq)	0	-26	-31	-23	-14	1	-26	-30	-23	-13	16	-10	-15	-7	2	16	-10	-14	-7	3	79	79	0	0	2	3	-7	-33	-37
ODP (kg CFC-11 eq)	0	-41	-40	-41	-42	1	-40	-40	-40	-41	2	-39	-39	-39	-40	3	-39	-38	-38	-40	23	23	22	23	29	30	-6	-47	-46
POCP (kg C ₂ H ₄ eq)	0	248	49	-16	641	5	253	54	-11	647	210	458	259	194	851	215	463	264	199	856	1129	1134	319	324	341	346	-17	231	32

CML 2001 baseline category (Unit)	External wall																														
	W3									W4									W5									W			
	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	6
ADP (kg Sb eq)	-41	-37	1	-43	-55	-38	-34	-65	-59	-62	-56	-19	-52	-61	-41	-45	-13	-46	-55	-35	-39	-15	-48	-58	-38	-41	-9	-42	-52	-32	-35
AP (kg SO ₂ eq)	-16	-11	-4	-16	2	-12	-7	-15	-17	-11	-13	0	-9	4	-3	-5	-2	-11	2	-5	-7	4	-5	8	1	-1	2	-7	6	-1	-3
EP (kg PO ₄ ³⁻ eq)	-41	-12	0	-24	73	-34	-5	-44	-41	-37	-35	-12	-40	8	-36	-38	-10	-38	10	-33	-35	-5	-33	15	-29	-31	-3	-31	17	-26	-28
GWP (kg CO ₂ eq)	-30	-20	-4	-30	-34	-27	-18	-31	-30	-28	-27	-5	-24	-28	-19	-19	-4	-24	-28	-18	-18	-2	-21	-25	-16	-16	-1	-21	-25	-15	-15
ODP (kg CFC-11 eq)	-47	-48	1	-40	-39	-40	-41	-41	-40	-33	-33	-8	-39	-39	-38	-40	-7	-38	-38	-37	-39	-1	-32	-31	-31	-32	0	-31	-31	-30	-32
POCP (kg C ₂ H ₄ eq)	-33	624	5	254	55	-11	647	-120	-115	-97	-92	-39	146	-9	-28	545	-34	152	-4	-23	550	-17	169	14	-6	568	-12	174	19	-1	573

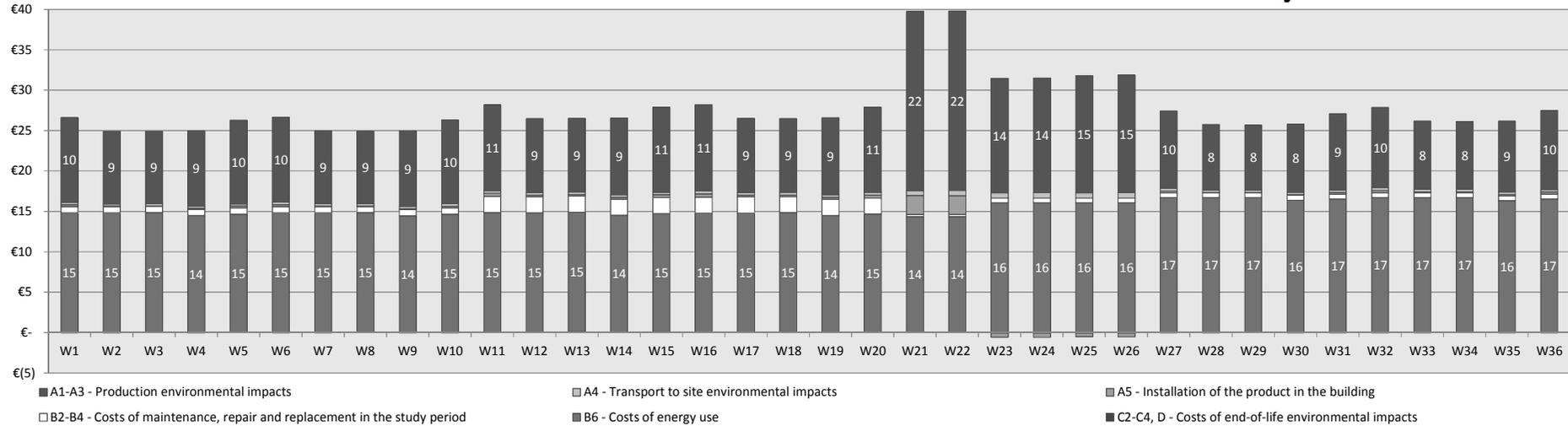
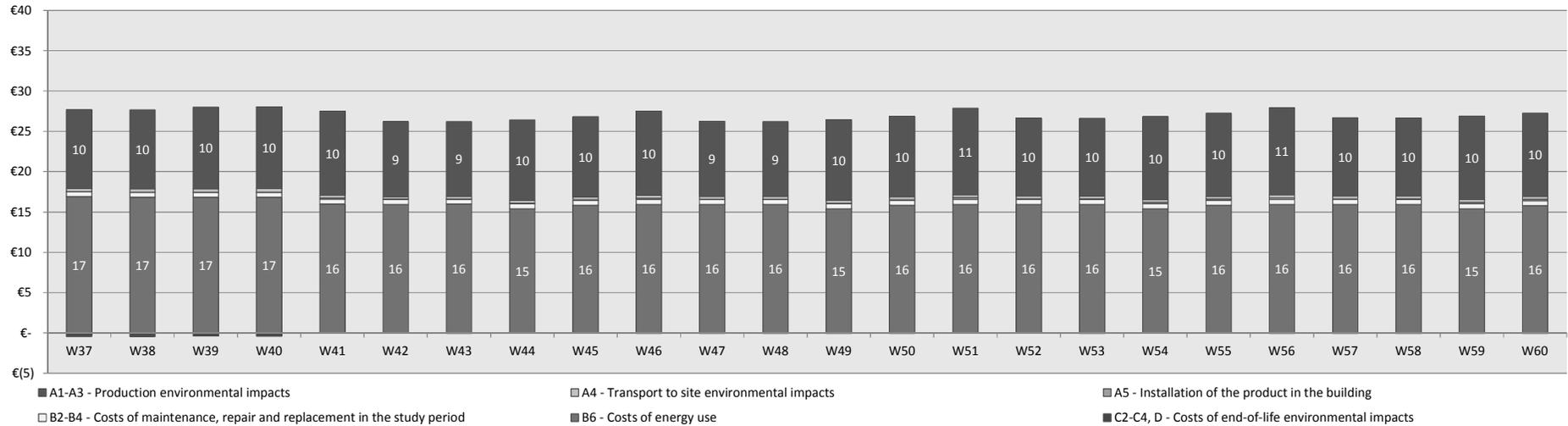


Figure 2 - NPV of the environmental (Cev) cost of single leaf walls with external, internal (W27-W36), and without (W23-W26), insulation



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Figure 3 - NPV of the environmental (Cev) cost of cavity walls

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Session 84:

How can we know which the best constructive solution is?

Chairperson:

Kratz, Markus

Forschungszentrum Jülich. Germany

Green infrastructure improvements for a more sustainable building sector

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Abstract: *Green roofs and green facades in buildings are new sustainable construction systems with many advantages compared to traditional ones, such as to decrease energy demand in buildings as well as to decrease the heat island effect in big cities, to control rain water run-off, and to increase the biomass as support of biodiversity in cities. With the aim to improve and adapt these constructive systems to the sustainable contemporary architecture and to the Horizon 2020 requirements, a long term research is being conducted both at lab and at pilot plant scale. First results show that current designs can be improved according to a more sustainable approach by the substitution of some materials, and that those systems have high potential to save energy, especially during cooling periods, under Mediterranean Continental Climate conditions.*

Key words: *green infrastructure; green roofs; green facades; green envelope; energy savings;*

1. Introduction

Green roofs and green facades are Green Infrastructure elements that provide several eco-services especially in urban environments. Those systems are currently highly valued by architects and engineers who broadly include them in their projects.

Among other green roofs systems, they offer interesting advantages over traditional building roof solutions. Some of these advantages are the reduction of surface runoff in large cities, the improvement of the urban environment, the support to biodiversity, the improvement of the durability of waterproofing materials, and especially energy savings [1-4]. But, although the constructive solution of these systems is designed according to a sustainable and environmentally friendly buildings approach, their design is still based on conventional materials such as polypropylene or polyester geotextiles membranes, polyethylene or polystyrene panels, expanded clay, natural pozzolana, and bitumen or PVC membranes. Thus, besides studying their functional benefits, also the study of the construction system itself must be considered.

According to these considerations, a long term research is conducted at the University of Lleida. In previous lab studies, the possibility of using rubber crumbs instead of pozzolana as drainage layer material in extensive green roofs was confirmed [5]. In addition the first studies at pilot plant scale about the thermal behaviour of this solution were started [6]. Generally it can be concluded that extensive green roofs can be a good tool to save energy during summer in Continental Mediterranean climate. Moreover, it was found that the use of

rubber crumbs instead of pozzolana as drainage layer material in extensive green roofs is possible and should not arise any problem for its good operation.

On the other hand, the use of green vertical systems (green facades and green walls), well designed and managed, can be a useful tool for thermal regulation for buildings with interested energy savings [7]. In previous studies the great capacity of double-skin green facade or green curtain to produce shade was confirmed, reducing the solar radiation on the facade wall of the building. It was also verified that a microclimate between the wall of the building and the green curtain is created, characterized by slightly lower temperatures and higher relative humidity [8-9]. But those studies took place in a real building, and some variables could not be controlled. Therefore, a new experiment to measure the effect of this construction system in controlled conditions was carried out and is presented here.

The aim of this paper is to summarize the main findings reached until now about these research activities on Green Infrastructure, and to describe the current research experiments and the most recent results about energy savings, conducted in pilot plant.

2. Materials and methods

2.1 Experimental set-up

The experimental set-up consists of several house-like cubicles (Figure 1) located in Puigverd de Lleida, Spain, with the same internal dimensions (2.4 x 2.4 x 2.4 m). Their bases consist of a mortar base of 3 x 3 m with crushed stones and reinforcing bars, and the walls present the following layers from the inside to outside; gypsum, alveolar brick (30 x 19 x 29 cm), and cement mortar finish [10-11].



Figure 1. Experimental cubicles in Puigverd de Lleida, Spain.

To evaluate the thermal performance of each roof and facade system the following data were registered for each cubicle at 5 min intervals:

- Internal wall temperatures (east, west, north, south, roof and floor) and also external south wall temperature.
- Internal ambient temperature and humidity (at a height of 1.5 m).
- Heat flux at the ceiling (inside).
- Electrical energy consumption of the heat pump.
- Global horizontal solar radiation.
- External ambient temperature and humidity.

All temperatures were measured using Pt-100 DIN B probes, calibrated with a maximum error of ± 0.3 °C. The air humidity sensors were ELEKTRONIK EE21FT6AA21 with an accuracy of $\pm 2\%$. The heat flux sensors used were HUKSFLUX HFP01 with an accuracy of $\pm 5\%$. The experimental set-up offers the possibility to perform two types of tests:

- Free floating temperature, where no heating/cooling system is used. The temperature conditions in the cubicles are compared.
- Controlled temperature, where the heat pump is used in summer and an electrical oil radiator is used in winter to set the internal ambient temperature of the cubicle. The energy consumption of the cubicles is compared using different set points. To span the spectrum of results some experiments were done using set points below the comfort range (experimental range: 16–24 °C; comfort range: 23–26 °C for summer and 20–24 °C for winter).

2.2 Green roofs

Three cubicles were used in these experiments, and the only difference between them is the construction system, of the roof (Figure 2):

- 1) Reference cubicle. A conventional roof with 3 cm of polyurethane and finished with a single layer of gravel of 7 cm thickness.
- 2) Pozzolana cubicle. An extensive green roof with a drainage layer of 4 cm of pozzolana directly below the substrate layer of 5 cm thickness, without insulation layer [12].
- 3) Rubber cubicle. An extensive green roof with a drainage layer of 4 cm of rubber crumbs directly below to the substrate layer, of 5 cm thickness, without insulation layer.

As irrigation is essential during the summertime in this climate, during 2011 a simple irrigation system was implemented. Also the planting of plants which are currently in a growth phase was undertaken (Figure 2).



Figure 2. Experimental roofs with 20-25% covered by plants.

2.3 Green facades

2.3.1 Previous facade system

Two cubicles were used in these experiments, and the differences between them are:

- 1) Reference cubicle (same as above). A conventional flat roof with 3 cm of polyurethane and finished with a single layer of gravel of 7 cm thickness.
- 2) Green facade cubicle. A conventional flat roof finished with a single layer of gravel of 7 cm thickness, without insulation layer, and the double-skin green facade installed in the south facade.

To perform this experiment four modular trellises prepared to accommodate a container garden at the bottom were designed and built (Figure 3). The facade was installed in south orientation.



Figure 3. Experimental cubicle with Double-Skin green facade.

The substrate used was a mixture of universal substrate for gardening and topsoil. The choice of plant species was made from a previous list of climbers made for the Mediterranean Continental climate. In the selection, the resistance of the species, the height they can reach, their adaptation to grow in modular trellis, and availability in nurseries, were considered. The species chosen were ivy (*Hedera helix*) and honeysuckle (*Lonicera japonica*), as perennial plants, and virginia creeper (*Parthenocissus quinquefolia*) and clematis (*Clematis sp.*), as deciduous plants.

2.3.2 Current facade systems

Two new cubicles were implemented in this study; one with Double_Skin Façade and other one with Green Wall system.

To perform the experiment with new Double_Skin Façade, a wire mesh on East, South and West facades were installed as shown in Figure 4. Boston Ivy (*Parthenocissus Tricuspidata*) is a well-adapted specie in the Mediterranean Continental climate selected to perform the experiments. The selection of the specie was based on the previous experiments.



Figure 4. (a) Cubicle with installed wire mesh; (b) newly planted Boston Ivy; (c) Growing phase of the Boston Ivy

On the other hand, to perform the experiment with a Green Wall system, an existing precultivated modular-based system, was implemented on the East, South and West facades of the cubicle [13]. The system is based on recycled polyethylene modules that are resistant to UV radiation and are 600 mm wide by 400 mm high and 80 mm thick (Figure 5). Each modular cultivation unit is a closed box filled with a recyclable and environmentally friendly substrate: coconut fibre.

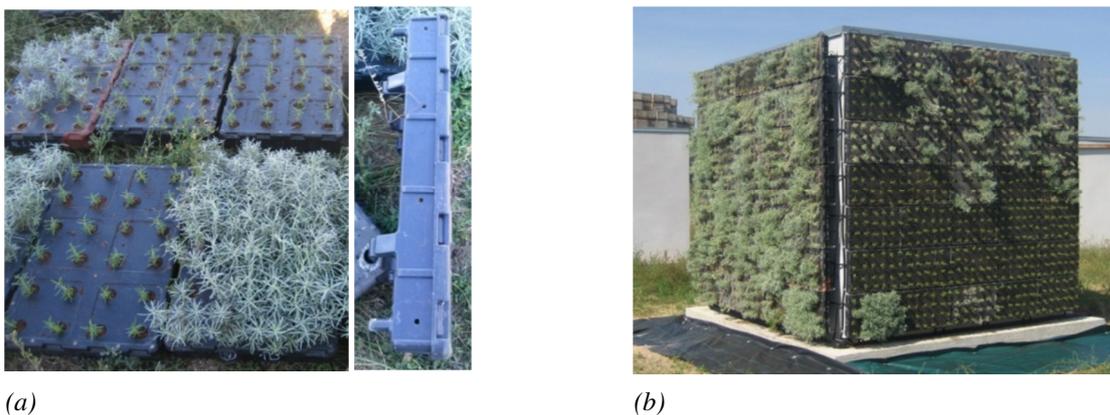


Figure 5. (a) Small garden containers; (b) Cubicle with Green Wall system

As plants were in the grown phase during year 2014, first data from the Green Wall systems is not yet available.

3. Results and discussion

3.1 Green roofs

As example, the controlled experiment with a set point of 24 °C is presented. Figure 6 shows the internal roof temperature of the studied cubicles. In the reference cubicle internal roof temperatures were around 24 °C during all representative week, while in the other cubicles more fluctuations were observed. Volcanic gravel and rubber crumbs roofs presents similar behaviour with a slightly differences in their values.

The accumulated energy consumption of the three cubicles can be observed in Figure 7. The reference cubicle has the highest electrical energy consumption followed by the rubber

crumbs cubicle and finally the volcanic gravel cubicle with the lowest consumption. Compared to the reference, the cubicle with volcanic gravel had 15% less energy consumption than the one with rubber crumbs (3.6%) during this representative period.

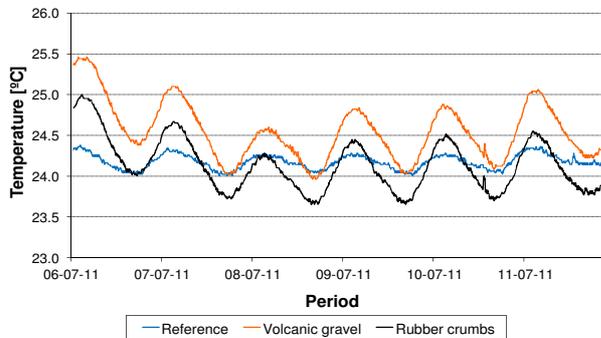


Figure 6. Internal ceiling temperatures. Controlled experiment (set point 24 °C).

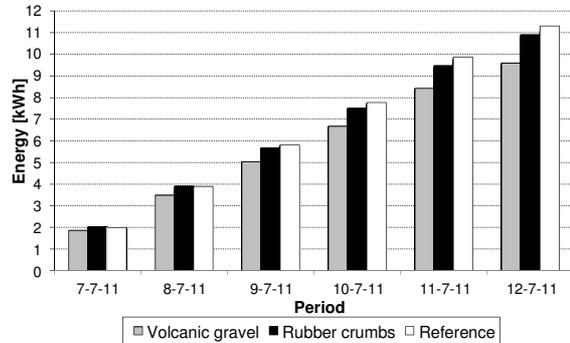


Figure 7. Accumulated energy consumption. Controlled temperature (set point 24°C).

Results of internal temperatures from free floating experiment are shown in Figure 8. An insulation effect can be seen in internal temperatures of the rubber crumbs cubicle as it has the lowest values. Reference cubicle temperatures were 1 °C above rubber crumbs cubicle and less than 0.5 °C from volcanic gravel cubicle.

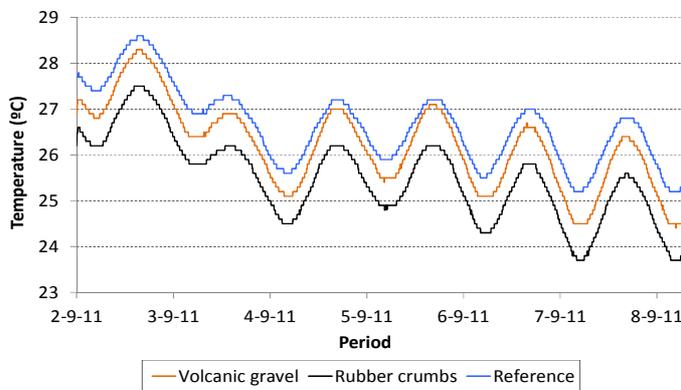


Figure 8. Internal ambient temperatures. Free floating experiment.

3.2 Green facades

3.2.1 Previous facade system

Again, as example the data obtained from the experiment with a set-point 24 °C is presented. Figure 9 shows the great potential of green facade to intercept solar radiation. This fact is evidenced by a reduction of up to 10 °C in the south wall external temperature of the cubicle with green facade. This evident shadow effect in the exterior wall only supposes a slight reduction in energy consumption. Thus the green facade cubicle has a 1% reduction in daily

consumption during this representative period of July. The final cumulative reduction in the analysed period is 5.5% (Figure 10).

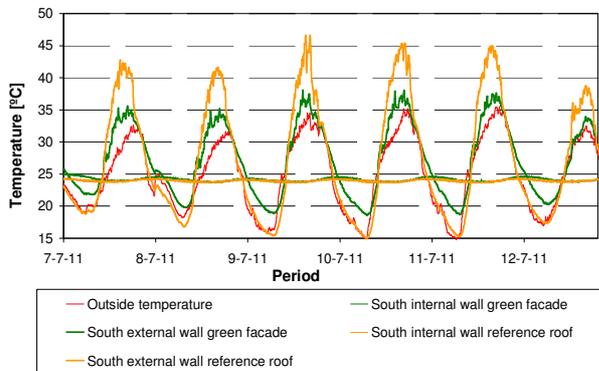


Figure 9. South internal and external wall temperatures. July 2011. Set-point 24 °C.

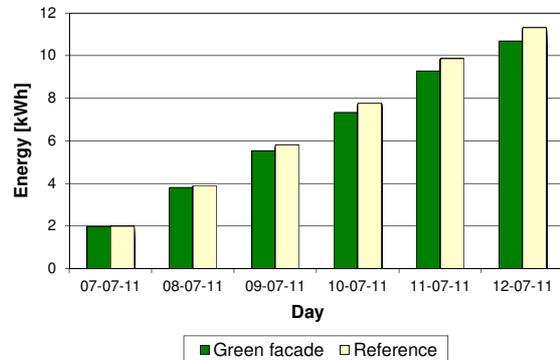


Figure 10. Accumulated energy consumption. July 2011. Set-point 24 °C.

Finally, in the results from September, with free floating regime, the shadow effect was still present on the south wall, reducing the external south surface temperature up to 14 °C in the green facade cubicle (Figure 11). This is also reflected in the south internal surface temperature of the green facade cubicle which was between 0.5 °C and 2 °C lower (Figure 11) than that of the reference one. In addition, the inside temperature was also about 1 °C lower in the green facade cubicle compared to the reference cubicle for this representative period (Figure 12).

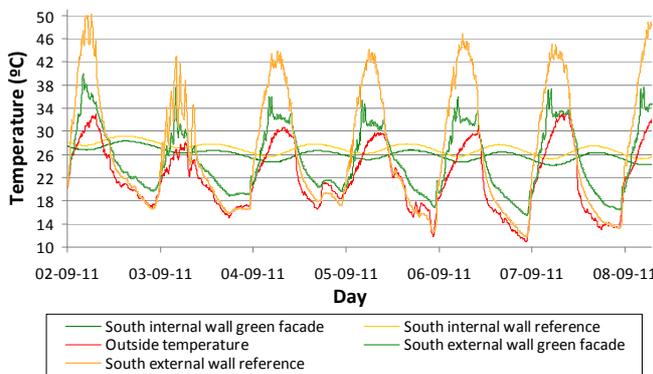


Figure 11. South wall temperatures. September 2011. Free floating temperature.

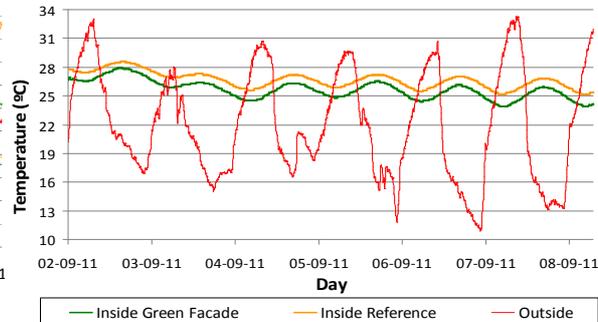


Figure 12. Internal temperatures. September 2011. Free floating temperature.

3.2.2 Current facade systems

In case of new Double-Skin green facade, first results of electrical energy consumption and thermal behaviour of a representative period during summer 2013 are presented below. Figure 13 shows the accumulated electrical energy consumption of the heat pumps of both cubicles, during 10 representative days of cooling period from 2013. Cubicle with new Double-Skin green facade shows 47% less energy consumed compared to the reference one, during this period.

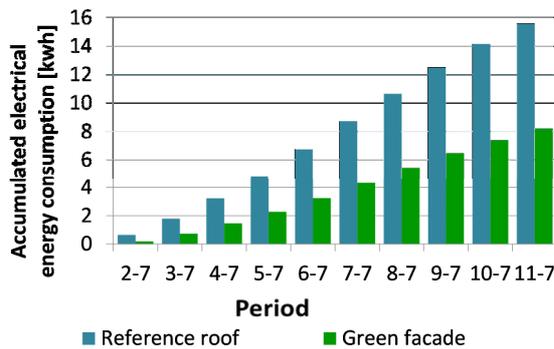


Figure 13. Accumulated electrical energy consumption. July 2013. Set-point 24 °C.

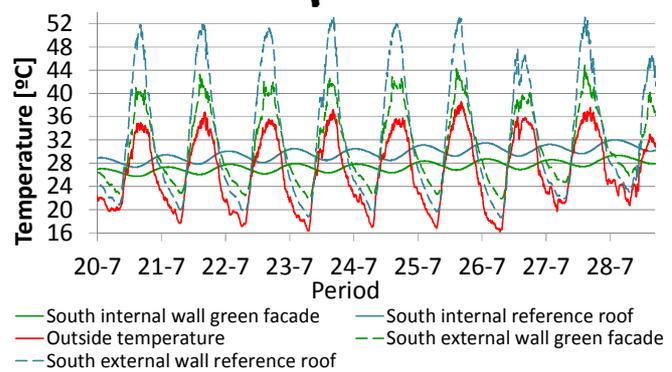


Figure 14. South wall temperatures. July 2013. Free floating temperature.

On the other hand, the thermal behaviour during representative period of 9 days of July 2013 without cooling and heating demand is presented in Figure 14. The south external surface temperatures of the Double-Skin green facade show a reduction of up to 13 °C compared to reference cubicle. This shadow effect is also reflected on the inside surface temperatures with a reductions of up to 2.6 °C when the cubicle with green facade is compared to reference one.

4. Conclusions

In the research presented here, the thermal behaviour of two different green roofs solutions is experimentally evaluated. Generally, these systems have high potential to save energy during summer in Continental Mediterranean climate. Even though, the experiments were done with 20% of total coverage plants, a good insulation effect has been observed comparing to traditional constructive solutions. In addition, the use of rubber crumbs as drainage layer material in extensive green roofs has a similar behaviour as volcanic gravel roof.

Studying the behaviour of green facades as passive systems for energy savings in buildings in Mediterranean Continental climate, during summer 2011 with a covering of approximately 50% of the south facade of an experimental cubicle the great capacity of the green facade to intercept solar radiation was confirmed with reductions in outside wall surface temperature up to 14 °C in late August and early September. However, in free floating regime during the first days of September, was verified that the shadow effect of the green facade has a direct impact on reducing the temperature inside the cubicle around of 1°C.

Cubicle with new Double-Skin green facade with a covering of approximately 80% of the East, South and West facades provides 47% electrical energy savings compared to the reference one during a representative cooling period of July 2013. In addition, under free floating conditions the shadow effect provided by this new green façade on the south wall shows reductions of up to 13 °C and 2.6 °C in external and internal surface temperatures respectively.



5. Acknowledgements

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Implementation of GIS methodology and passive strategies to improve the quality of social housing in the Andean region of Ecuador

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Abstract: *The present study evaluates the application of passive strategies in the construction of social houses for the Andean region of Ecuador. To perform the evaluation, it was necessary to define climate zones of the region. A simplified climate zoning (based on temperature and relative humidity) was employed through the use of geographic information systems (GIS) and the Givoni's psychrometric chart. As a result of this methodology, six climate zones were identified in the Andean region. Different passive strategies were then assigned for each climate zone according to Givoni's bioclimatic approach. Finally, building energy simulation tool was used to validate the implemented passive strategies for each zone. A reference model of social house with the most common building fabrics used in the region was designed for that purpose. The results show that employment of Givoni's passive strategies can lead up to 90% of annual hours within the thermal comfort conditions.*

Keywords: *climate zoning, GIS, passive strategies, social housing, Ecuador*

Introduction

Latin America is facing evident problems with respect to the deficit and the poor quality of social housing. According to the study of Funaro [1], 130 million families inhabit in urban areas of Latin America. About 42 million of these families live below the threshold of normal living conditions, without resources to repair their dwellings and, in many cases, sharing the dwelling with other families. The policies implemented in the region mainly focus on the provision of new housing units, though the main problem is qualitative [2]. The quality issue directly affects the users' thermal comfort, which indicates the need for improving housing from the design stage. With respect to that, the analysis of weather conditions is the starting point for the design of bioclimatic architecture with two main objectives: first, to maximize comfort conditions and second, to minimize energy consumption [3]. Most of the current climate classifications correlate vegetation values and climate models. Globally recognized climate classification models are: Köppen, Thornthwaite, Gaussen Troll & Paffen, Holdridge, Walter and Box. Rivas-Martínez [4] discussed these climate models in his review, highlighting the problem of grouping various climate conditions in the same category. These models have been used to support the definition of energy efficiency measures in several countries, although this is not their main purpose.

The implementation of passive strategies, with respect to the climate conditions of a region, can reduce energy consumption in buildings while maintaining an acceptable thermal comfort. In fact, Milne and Givoni [5] affirm that if the outside temperature is between 7 and 35 °C with a relative humidity greater than 30%, the indoor comfort conditions can be maintained without the need for mechanical systems. Building shape, orientation, shading

devices, wall colours, size and location of windows and natural ventilation are the most influential passive design factors according to the study of Givoni [3]. The use of passive strategies in social housing construction can significantly reduce the energy consumption of active systems, particularly in countries with extreme climates [6]. Passive strategies can also be applied to construct social houses with acceptable thermal comfort conditions in low-latitude countries like Ecuador. This concept is applicable mainly in the Andean region where the temperature varies between -6 and 27 °C. On the other hand, there are several existing problems, which hinder energy efficient constructions in Ecuador. A key problem, as mentioned previously, is the regional trend of qualitative deficit in social housing. The construction standards and codes in the country are focused only on architectural, structural and safety issues. With respect to this problem, the definition of effective passive strategies, as a function of climate conditions, is crucial for the future development of energy efficiency guidelines in the country. The second problem is the current design of social houses in different regions of Ecuador, which assumes almost a homogeneous climate since the country does not present four seasons. However, according to the conducted agro-ecological studies, various factors such as the Andean mountains, ocean currents and the inter-tropical convergence zone have a big influence on the creation of local climates. The last problem is the lack of meteorological data that prevents accurate analyses with more details. In the case of most meteorological stations, only daily or monthly average values data are available.

According to this background, this study aims to present a methodology, which can improve the quality of social house construction in the Andean region of Ecuador. The result of the methodology is a simplified climate zoning of the Andean region with the recommended passive strategies for each zone. The zones were defined based on monthly averages data of relative humidity and ambient temperature by involving GIS mapping software and the Givoni's psychrometric chart. The final stage of the methodology evaluates the recommended passive strategies for the Andean Region by employing energy simulation software.

Methodology

The idea of promoting an efficient construction system for social housing in Ecuador raised the issue of climate zoning. However, the complexity of the Ecuadorian climate and the lack of available meteorological data limited the focus of the study only to the Andean region of the country. This region covers an area of approximately 104,000 km², with terrain altitude between 700 and 6300 m.a.s.l. The proposed methodology consists of three phases: Definition of climate zoning ranges, climate zoning and validation of the method.

a. Definition of climate zoning ranges

Air temperature (T_a) and relative humidity (RH) were selected as parameters to define climate zoning ranges. Based on these parameters, the applied zoning methodology resulted with the identification of six climate ranges for the region. For zones 1a and 1b, the ranges were defined based on the ASHRAE standard 55 [7], considering a clothing level (clo) of 0.50 and 1.00. For zones 2 to 5 the ranges were defined based on the theoretical work of Givoni and Milne [5] used in Climate Consultant tool [8]. According to the authors, the corresponding

strategies for cold climates are internal heat gain, passive solar direct gain with low mass and high mass and active heating. Passive strategies for warm humid climate are not considered since the average ambient temperature in the Andean region does not exceed 30 °C. The considered ranges of T_a and RH as well as the correspondent passive strategies to reach the indoor comfort temperature for each climate zone are shown in Table 1.

Table 1. Climate zoning ranges in the Andean region with recommended passive strategies

Zone	Passive strategy	clo	Min		Max	
			T_a [°C]	RH [%]	T_a [°C]	RH [%]
1a	Comfort range	1	19.6	86	23.9	66
			21.4	20	25.7	15
1b	Comfort range	0.5	22.9	67	26.1	56
			24.7	16	27.9	13
2	Internal heat gain	1	15.6	100	23.9	100
			17.4	0	25.7	0
3	Passive solar direct gain-low mass	1	11.6	100	23.9	100
			13.4	0	25.7	0
4	Passive solar direct gain-high mass	1	7.0	100	23.9	100
			8.8	0	25.7	0
5	Active Heating	1	< 7	100	< 7	0

b. Climate zoning of the Andean region

Once the zoning parameters were defined, the meteorological data were analysed and processed. Normal monthly values of T_a and RH for the period 1993-2013 were obtained from the database of the National Institute of Meteorology and Hydrology (INAMHI) [9]. A quality analysis of the data series was performed through the Alexandersson and Moberg's Standard Normal Homogeneity Test [10]. Then, based on the homogenized data, raster models with T_a and RH values were generated for the Andean region using Fries et al. regionalization techniques [11]. According to the authors, raster models of altitude (z), atmospheric pressure (P_a) and vegetation cover are necessary to generate the maps. In consequence, Shuttle Radar Topography Mission (SRTM) data base [12] was employed to obtain z and P_a for each x and y point by employing Equation 1:

$$P_{a(x,y)} = 1164.25e^{-0.000149803z} \quad (1)$$

Since there is no vegetation cover model for the Andean region, the normalized difference vegetation index (NDVI) was used. As a result, the maps of T_a and RH corrected for the Andean region were obtained.

The next step in the methodology was categorization of each map point to the corresponding zone according to Table 1. To apply the range on the map, it was necessary to define equations that would delimit climate zones. To facilitate this process, RH values were converted into humidity ratio (H), using the Equation 2 [13]. Here, RH is the decimal relative humidity and P_s is the saturation steam pressure at dry bulb temperature. Figure 1 shows the ranges of each zone.

$$H = \frac{0.6219P_sRH}{P_a - P_sRH} \tag{2}$$

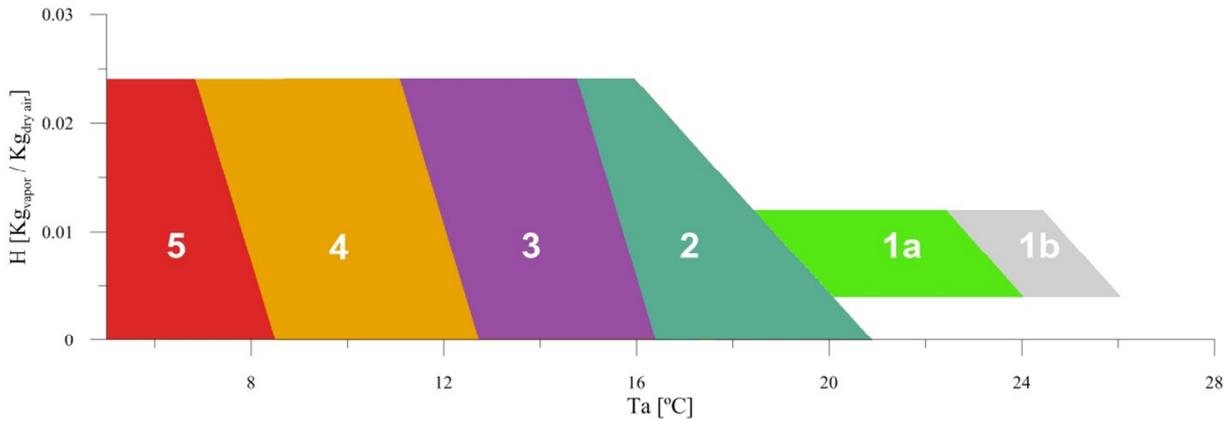


Figure 1. T_a and H ranges for the defined climate zones

The straight lines that define the maximum and minimum H values for each zone correspond to a linear function, where slope m is equal to zero while intercept b is a constant for each zone. On the other hand, the temperature limits lines also correspond to linear function where b varies according to the zone and m is a constant different from zero. Table 2 shows the m and b values for each zone. Equation 3 was employed to calculate m , using the limit values of H and T_a in each zone. Equation 4 was used to calculate b coefficient for the upper and lower temperature limits.

$$m = \frac{H_{max} - H_{min}}{T_{amax} - T_{amin}} \tag{3}$$

$$H = b - mT_a \tag{4}$$

Table 2. Coefficients m and b for the different climate zones

Zone	Passive strategy	Slope m	Intercept b (range)
1a	Comfort range	$m_1 = -0.004$	0.099-0.118
1b	Comfort range		0.118-0.128
2	Internal heat gain	$m_2 = -0.013$	0.233-0.345
3	Passive solar direct gain low mass		0.179-0.233
4	Passive solar direct gain high mass		0.118-0.179
5	Active heating		< 0.118

To generate climate zoning map with GIS tool, it was necessary to calculate intercept (b) values for each T_a and RH point in the map through Equation 5. All models and calculations for the maps were processed in Idrisi Selva [14], a GIS tool specialized in raster analysis.

$$b_{(xy)} = H_{(xy)} - mT_{a(xy)} \tag{5}$$

c. Validation

In order to validate the applicability of the passive strategies for the different zones, energy simulations were performed using DesignBuilder software [15]. At this stage, it was necessary to have at least one weather file for each climate zone. As previously mentioned, the weather information for the Andean region is limited. For this reason, weather files were generated using Meteonorm software [16]. Since the software uses few reference data for weather file generation in the Andean region, it was necessary to validate the generated files. To this end, the correlation between Meteonorm and INAMHI [9] data was analysed, based on monthly averages values of T_a and RH . The minimum level of correlation was set to 65% for each zone, with the aim of ensuring acceptable weather file. The house input parameters (building fabrics, glazing and shape) must be defined to run the energy simulations. In the literature, some studies use the common building characteristics for selected climates as input data [17]. This approach was followed since the Givoni's method does not define the housing type in which the passive strategies can be applied. With the same approach, two cases were designed for each zone. The base case (BC) is a social house whose fabrics, glazing and shape were determined according to the data from the latest regional Census of Population and Housing [18]. Case two or proposal case (PC) uses the BC as starting point, modifying the fabrics according to the strategies for each zone. The design and the internal space distribution of the reference house model, which has an area of 45 m², are shown in Figure 2. Input data for occupant density and schedules, equipment gains, lighting gains, shape, orientation and window to wall ratio (40% glazing on two opposite facades) were set equal for each zone (Table 3). Table 4 shows the building fabrics U-values used in the simulations for each zone (for both BC and PC).

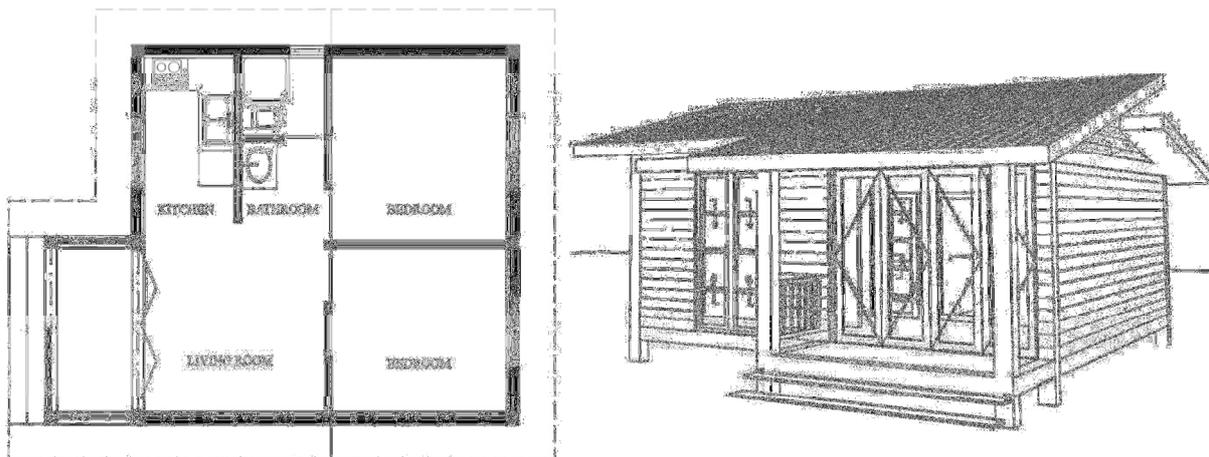


Figure 2. Reference house model

The simulation results were analysed through the percentage of annual hours within the comfort range according to the indoor operating temperature. The reference values were obtained using the Climate Consultant tool. This tool estimates the improvements which house can achieve with the implementation of passive strategies based only on the weather file. By comparing the simulation results of the PC with the reference values of Climate Consultant, the effectiveness of the implemented passive strategies can be validated.

Additionally, the simulation results of the BC and PC were compared in order to evaluate the improvement in comfort percentage with the use of the corresponding passive strategies for each zone.

Table 3. Main simulation parameters for the prototype house

	Occupancy	Lighting	Equipment	Infiltration		
Internal Loads	0.10 people/m ²	5 W/m ²	14.50 W/m ²	0.70 ac/h		
Schedule/Ratio		00h00-06h00	0.00	00h00-07h00	0.07	
		06h00-08h00	0.50	07h00-08h00	0.53	
	00h00-07h00	1.00	08h00-09h00	1.00	08h00-09h00	1.00
	07h00-08h00	0.50	09h00-17h00	0.00	09h00-17h00	0.07
	08h00-09h00	0.25	17h00-18h00	0.25	17h00-18h00	0.03
	09h00-17h00	0.00	18h00-19h00	0.50	18h00-19h00	0.53
	17h00-20h00	0.75	19h00-20h00	0.75	19h00-20h00	0.77
	20h00-24h00	1.00	20h00-22h00	1.00	20h00-22h00	1.00
			22h00-23h00	0.75	22h00-23h00	0.77
		23h00-24h00	0.25	23h00-24h00	0.30	

Table 4. U-values of building fabrics used in simulations

Zone	Passive Strategy	Floor [W/m ² K]	Walls [W/m ² K]	Roof [W/m ² K]	Glazing Type [W/m ² K]
1a	Base Case (None strategy)	2.475	2.718	3.448	6.121
1b	Base Case (None strategy)	2.475	2.718	3.448	6.121
2	Internal gains	2.475	1.007	0.649	6.121
3	Passive solar direct gain-Low mass	0.547*	0.659*	0.670*	2.708
4	Passive solar direct gain-High mass	0.325**	0.361**	0.365**	2.708
5	Active heating system	0.325**	0.361**	0.365**	2.708

* Low thermal mass (Internal heat capacity between 189.56 kJ/m²K – 221.78 kJ/m²K)

** High thermal mass (Internal heat capacity over 221.78 kJ/m²K)

Results and Discussion

According to the analysed meteorological data, T_a in the Andean region varies between -6 and 27 °C. The lowest temperatures occur in the high mountain zones. The values of RH vary between 66.3 and 85.6%. The spatial variation of RH depends on many factors including the temperature oscillation (ΔT_a), altitude (z) and vegetation cover conditions. After performing the calculations, six climate zones were defined (Figure 3). The Zone 1a covers 33% of the Andean region. This zone covers the area located in the eastern lowland foothills where the vegetation is exuberant. Zone 3 is the second largest zone, covering a 20% of the region. It is mainly located in the middle mountains where altitude does not exceed 3042 m.a.s.l. A 13% of the studied area corresponds to the high mountain zone (Zone 5). This zone is over 3500 m.a.s.l with average temperature below 7 °C. The BC and PC simulation results for each weather file (corresponding to different zones) are shown in Figure 4. Internal comfort ranges were defined according to the study of Givoni [19]. For Zone 1b, thermal comfort conditions were considered when the temperature range was between 20 and 27 °C (0.5 clo) while the considered thermal comfort range for all other zones (Zones 1a to 5) was between 18 and 25.7 °C (1 clo).

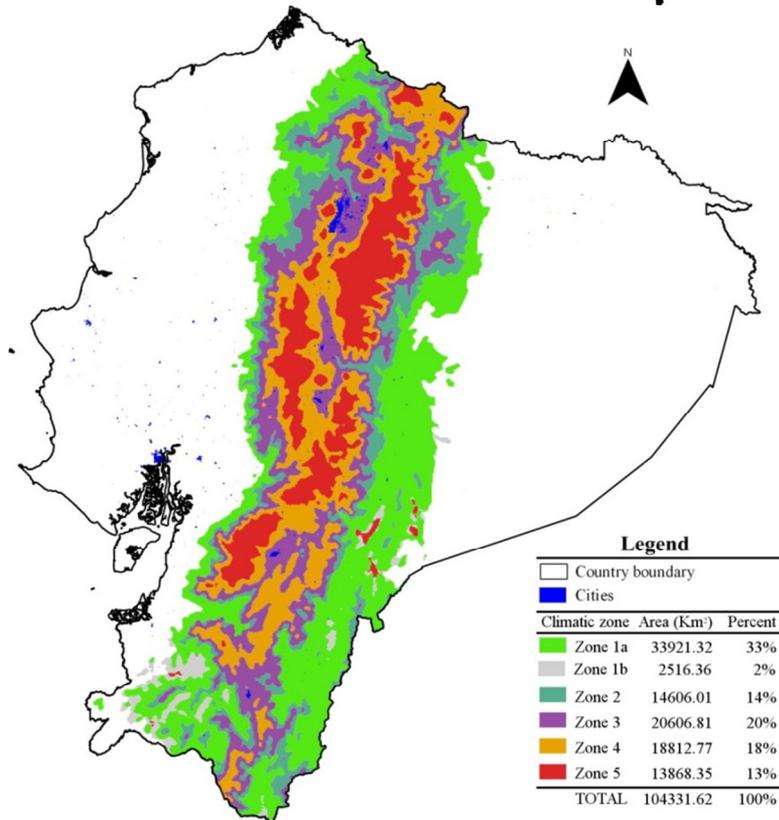


Figure 3. Climate zoning map

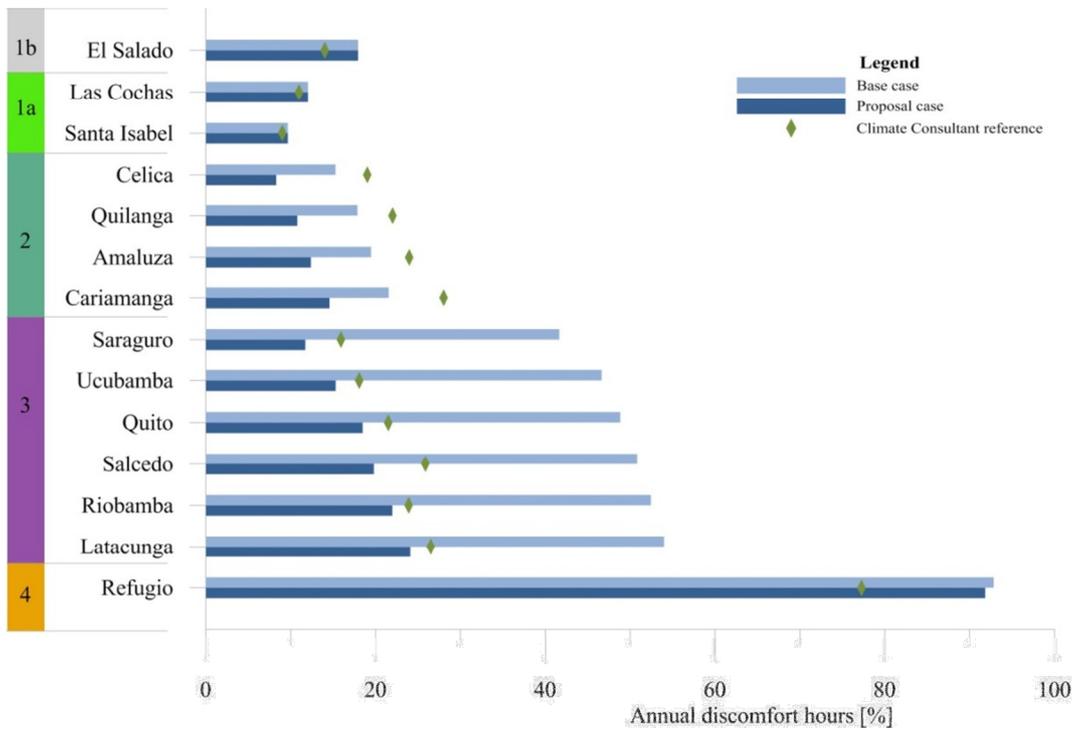


Figure 4. Percentage of discomfort hours per year

The percentage of annual hours in the thermal comfort range for the BC varies between 7.17 (Zone 5) and 90.34% (Zone 1a). Zones 1a and 1b do not implement passive strategies since discomfort ranges are less than 15% using the BC. However, it is highly recommended to



insulate the roof in order to reduce to the maximal internal temperature up to 2 degrees. On the other hand, in Zone 2, the BC discomfort ranges vary between 16 and 22%. By insulating the roof and the exterior walls, the discomfort ranges were reduced by 7%. East-West windows orientation, insulation and thermal mass in the envelope (roof, walls and floor) were the applied strategies in Zone 3, in order to achieve acceptable comfort levels. Solar gains maximization and the use of high thermal mass fabrics in the envelope were the strategies corresponding to Zone 4. Even after implementation of these strategies, only 8.17% of the annual hours reach the comfort range. However, the indoor temperature is above 14 °C during 78% of the annual hours. No simulation results are presented for Zone 5 since there is no valid weather file and there are no large habitable areas in this zone. The logical recommendation for Zone 5 is to have at least the same thermal mass and insulation level as Zone 4. In addition, the conclusion for both Zones 4 and 5 is the obvious need for active strategies implementation in order to satisfy the heating demand and to reach thermal comfort conditions.

Conclusions

This study is the first step of the project, which aims to define complex climate zoning of Ecuador and to promote efficient construction strategies for social housing. Through this study, it was shown that the climate zoning based on T_a and RH from Givoni's strategies is applicable to the Andean region of Ecuador. The results of this study demonstrated that the implementation of adequate passive strategies in each zone can provide an acceptable thermal comfort conditions up to 90% of annual hours, without the need for active systems. Such strategies could significantly improve the quality of life in Ecuador having in mind that 44.53% of Ecuadorian population lives in the Andean region. Since the main cities in the Andean region belong to the Zone 3, the use of low thermal mass materials and solar gains maximization can improve the living conditions of many families. Thermal mass strategy has been commonly employed in vernacular housing all over the region (mainly in rural areas) where adobe bricks and clay tiles are used as thermal mass materials. Although these vernacular fabrics were not used for simulations, their properties are similar to those used for Zone 3.

Future research seeks to replicate the process of climate zoning to the others regions of the Ecuador. This requires valid meteorological data from Coastal and Amazonian region as well as from Galapagos Islands. The zoning has to be redefined considering the vegetation conditions of each zone since they were missing in the present study. With a redefined zoning of the whole country, the next step would be to develop a guideline that defines efficient use of building fabrics and passive strategies for each zone, which would lead to the improvement of the current construction systems used in social housing.

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Retrofitting with prefabricated modules. Stakeholders' views and needs

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Abstract: *This paper is based on work carried out in RetroKit, Toolboxes for systemic retrofitting within the FP7 programme. The scope of the presented work is to identify the views and thoughts of stakeholders on the use of prefabricated modules in retrofitting of apartment buildings. Quantitative methodology in the form of a questionnaire has been used to provide data in 11 European countries. The intension with our research is to provide indicators with which to understand societal trends associated with deep retrofitting in general and retrofitting with prefab in particular. The main research questions are: What characterizes good retrofitting design? What are the success criteria for prefabricated solutions? What are the architectural requirements for prefabricated modules? The findings show that the three most referenced characteristics of good retrofitting design are energy efficiency, cost and aesthetics. The greatest pitfalls associated with prefabrication were seen as limited architectural freedom resulting in poor architecture.*

Keywords: *Retrofitting, Prefabrications, Stakeholders, Architecture, Energy*

Introduction

Multi-family apartment buildings constitute more than 50% of the EU building stock and the building typology consumed 68% of the total final energy use in buildings in Europe in 2009 [1]. The majority of these buildings were built between 1945 and 1980 and are now ready for retrofitting. A huge energy-saving potential is within reach if priorities are right. The apartment buildings are located all around Europe and share many common features like architecture, structure and materials. This makes them suitable for retrofitting with prefabricated modules which allow for cost efficient mass production. Building service technologies can be integrated in the modules and the residents can stay in their homes during retrofitting. To make sure that good retrofitting concepts and solutions are developed, knowledge on the needs and views of stakeholders involved in retrofitting is crucial [2]. Research show that retrofitting solutions should address more than just energy efficiency to be attractive. Added benefits such as improved indoor environmental quality and architectural expression should be part of the retrofitting concept, as energy efficiency is not always the primary driver for upgrading [3]. The objective of the questionnaire survey is to identify the views and thoughts of stakeholders involved in retrofitting about the use of prefabricated modules for retrofitting. The survey covers Poland, Romania, Germany, Switzerland, Ireland, Italy, Spain, Greece, Sweden, Norway and The Netherlands. The informants were building



owners, architects, consultants, contractors, prefab manufacturers and authorities. The main research questions are: What characterizes good retrofitting design? What are the success criteria for prefabricated solutions? What are the architectural requirements for prefabricated modules?

Method

Quantitative research methodology in the form of a questionnaire has been used to provide data about the use of and expectations related to retrofitting with prefabricated modules. The quantitative research approach has its roots in positivist theory where the intention is to empirically test hypotheses explaining and predicting the what, where, why, how and when phenomena occur [4]. However, due to the exploratory nature of our research, the intention has not been to test a hypothesis but to provide indicators with which to understand societal trends associated with retrofitting using prefabricated modules. Quantitative methods, such as questionnaires, provide numbers and offer the means to understand, describe, and explain them. Quantitative research relies on an objective standpoint, where different points of view may be compared and the research results can be verified, if necessary, at a later date [5]. Hence, if the questionnaire survey were to be repeated, the results should be the same. However, the questions in our survey are not of a nature which is easily quantifiable. The respondents are not asked, for example, to number how many prefab projects they have participated in, rather they are asked about architectural requirements and success criteria from their point of view. These aspects are based to a large degree on subjective experience and taste, making the answers more subject to fluctuation. It is hard to measure subjective data quantitatively [6]. The data from the questionnaire does not give in-depth information on the respondents' motivations, standpoints or personal perceptions. The data from the questionnaire instead provides indicators about societal requirements, success criteria for prefab solutions and characteristics of good retrofitting design.

The questionnaire was developed in an iterative process amongst the researchers in the RetroKit consortium and then tested on a representative test group before it was presented in its final digital form¹. The questionnaire consists of 16 questions arranged in four thematic sections. The questions fall primarily in the ordinal-polytomous category, where the respondent has more than two ordered options. The survey was conducted during the spring of 2013 using the electronic questionnaires system EasySurvey [7]. The majority of the informants were approached using e-mail invitation to participate in the survey. The invitation was sent to 4697 genuine e-mail addresses among the target group in the 11 countries. A total of 526 answered the questionnaire, giving a response rate of ca. 12%. It is not possible to draw 100% reliable conclusions on this empirical data set, but the material gives a good indication about the views and needs of the stakeholders involved in retrofitting. The distribution of answers is shown by role in figure 1 and by country in figure 2. Norway,

¹

<https://response.easyresearch.se/s.asp?ID=141256379&Pwd=ANKP7WOM&QID=3237842&TESTMODE=true>

Germany and Spain stand out with the highest response rates. Architects dominate the response rate in Germany and Spain while authorities dominate the response rate in Norway.

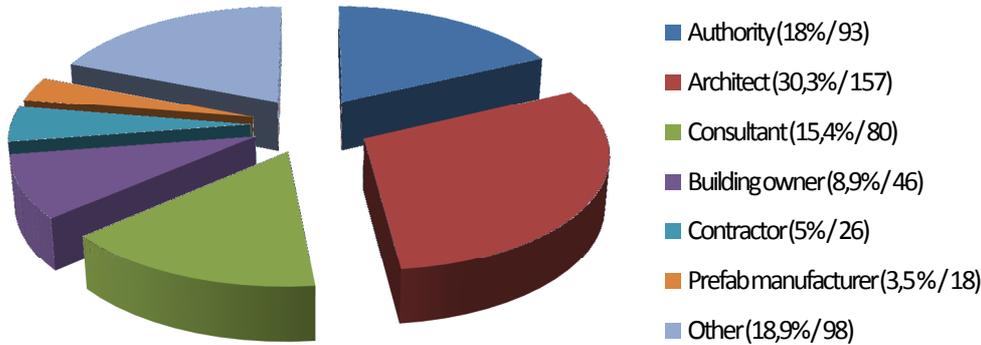


Figure 1 Distribution of answers in relation to role. The two numbers in parenthesis separated by a slash denotes the percentage of answers and the number of answers (frequency) for that group.

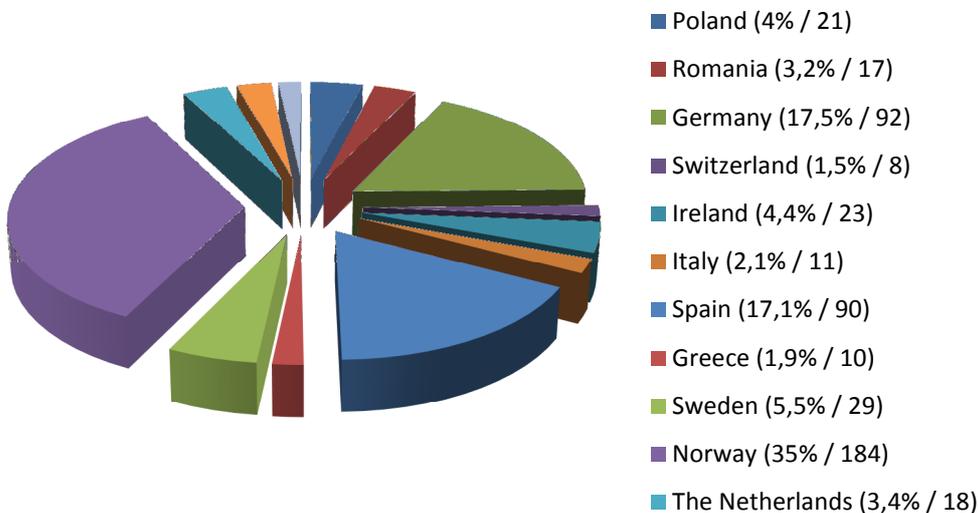


Figure 2 Distribution of answers in relation to country. The two numbers in parenthesis separated by a slash denotes the percentage of answers and the number count of answers (frequency).

Findings

The respondents were initially asked to rate their knowledge and experience with ambitious retrofitting as well as their experience in using prefabricated modules. The results show that there is more knowledge than practical experience with ambitious retrofitting even though approximately 2/3 of the respondents have experience with ambitious retrofitting, see figure 3. When it comes to the experience in using prefabricated elements only 6% report extensive

experience while 43% report limited experience. This indicates that on site production in the traditional way is more widespread than the utilisation of prefab modules.

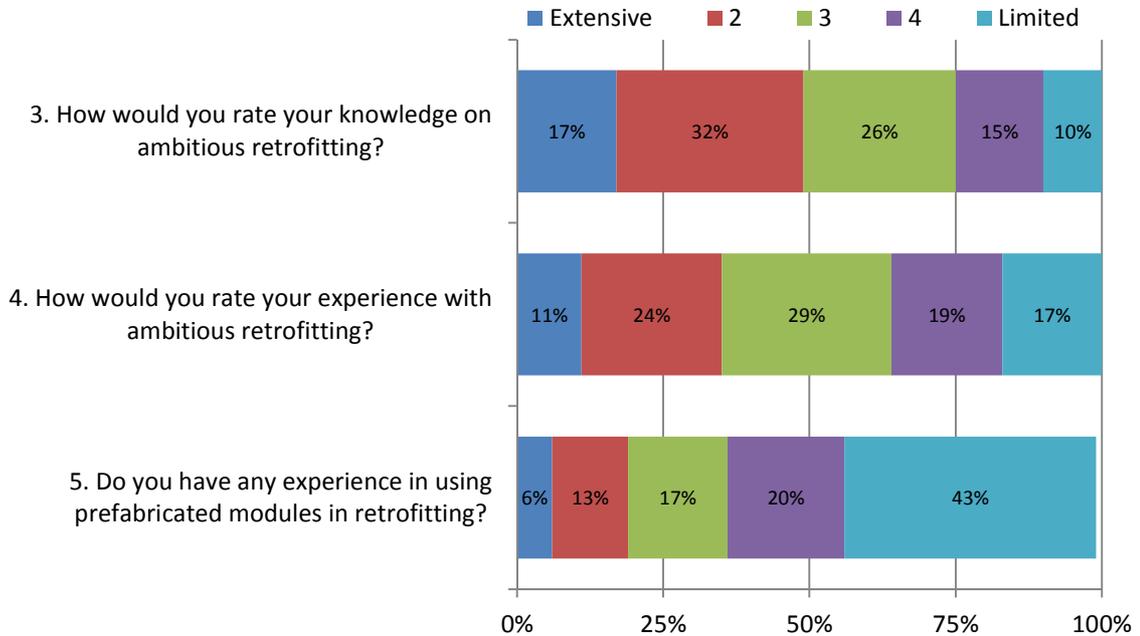


Figure 3 The respondents self-rating of own knowledge and experience with ambitious retrofitting (top and middle) and experience in using prefabricated modules in retrofitting (bottom).

The respondents were asked if they were aware of the regulation requirements for retrofitting in their country, and in a follow up question they were asked to point out the main challenges with the regulations as they see them. More than half of the respondents are not fully aware of the regulation requirements for retrofitting in their country. Incompleteness was reported as the greatest weakness associated with the regulations for retrofitting, and a generally negative response was document among the respondents pointing to frustration, confusion and inefficiency.

In order to find out which qualities a prefabricated retrofitting module should possess the respondents were asked which criteria (i.e. characteristics) would be most important in their choice of a particular prefab system for deep renovation. The respondents were asked to rate the importance of 11 different criteria on a scale from 1 (not important) to 5 (very important).

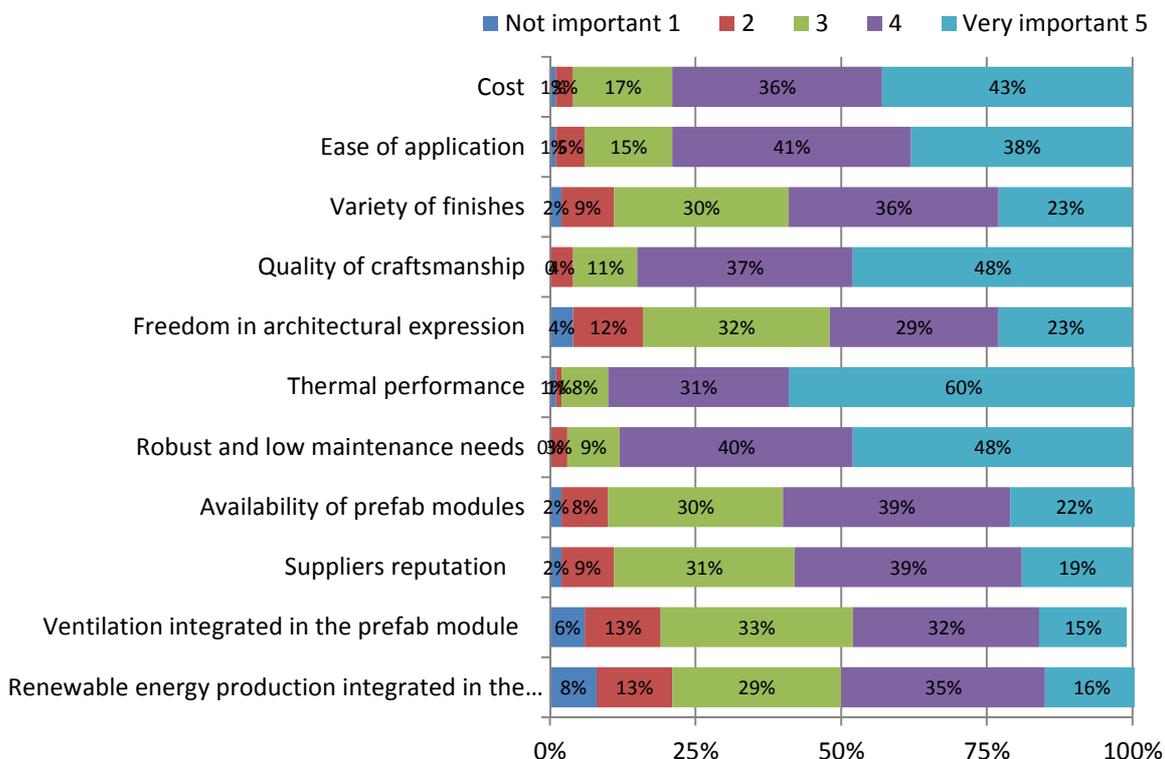


Figure 4 The respondents' answers to the question: What would be the most important criteria in your choice of a particular prefab system for deep renovation?

By summarising score 4 and 5 for each criteria and ranging them by importance we can reveal a profile which suggests the mutual importance of the different criteria. The three criteria receiving the highest score were *Thermal performance* (91%), *Robust and low maintenance needs* (88%) and *Quality of craftsmanship* (85%). These three leading criteria were closely followed by *Cost* (79%) and *Ease of application* (79%). Then there is a step down to the next three criteria which scored within the range of 58-61%, namely *Availability of prefab modules*, *Variety of finishes* and *Suppliers reputation*. Finally, the least important criteria are *Freedom in architectural expression* (52%), *Renewable energy production integrated in the prefab module* (51%) and *Ventilation integrated in the prefab module* (47%). It can be argued that all the criteria are rated important as most receive a score above 50%, but it is still possible to rank them. The low score on "Freedom in architectural expression" is rather surprising considering the high response rate from architects.

In order to uncover the difference between prefabricated and on site production the respondents were asked to identify the advantages and the pitfalls of retrofitting with prefabricated modules as opposed to on site production the traditional way. The advantages of prefabricated modules lie primarily within the practical implementation of a retrofitting project. Respondents suggest that retrofitting with prefab modules will encourage *efficient construction*, make it *easier to secure a dry building* and cause *fewer building defects*. *Improved built quality* also scores high as an advantage with prefabricated modules. In



addition, 72% of respondents believe that retrofitting with prefabricated modules will cause less disruption for residents during the renovation process.

The pitfalls of prefabricated modules lie primarily within the field of architectural expression and high costs. *Limited architectural freedom* was regarded as the greatest pitfall of retrofitting with prefabricated modules. *Cost* was regarded as the second greatest pitfall, implying that many of the respondents see prefab as a more costly way of retrofitting than on site production in the traditional way. The third greatest pitfall was that retrofitting with prefabricated modules will result in *poor architecture*. The latter being the logical outcome of limited architectural freedom in the design phase.

The respondents were asked to select the 5 most important requirements a prefab system would have to meet to be attractive from a list of 9 requirements. They were also given the possibility to elaborate in their own words, but only 20 respondents did that. It is unclear whether the multiple choice options cover the field well enough, or whether the respondent did not take the time to fill in comments. The answers given in the comments relate to low maintenance needs and the safeguard of cultural and historical values. Summing up all the responses provides the following five architectural requirements a prefab solution should meet to be attractive (by importance): Energy performance, Adaptability to the building, Efficient construction, Flexibility in design (room for tailoring) and Adaptability to the residents' needs.

In a follow up question to the theme of flexibility in design, the respondents were asked to rate the importance of various aspects related to flexibility in architectural design, see figure 5. More than half of the respondents consider all the suggested aspects as important, but *Precision of joints and connections* stand out as most important of all. 88% of the respondents rate it either as very important (60%) or as important (28%). There are minor variations in importance among the other aspect. *Surface material (texture, colour)* is the second most important aspect where 65% rated it either as very important (24%) or as important (41%). *Proportion of module (shape)* and *Integration of solar shading devices* were rated equally important with a score of 59% and 58% respectively (important and very important summarized). *Possibility for creating relief in the facade (depth, rhythm)* was considered as the least important aspect with regard to flexibility in architectural design. 43% of the respondents rate it either as very important (14%) or as important (29%). It can be argued that all the suggested aspects are important for the flexibility in architectural design as all score over 50% on very important or important (except for relief in the facade). This is confirmed by the low score all aspects received for "not important", less than 6%.

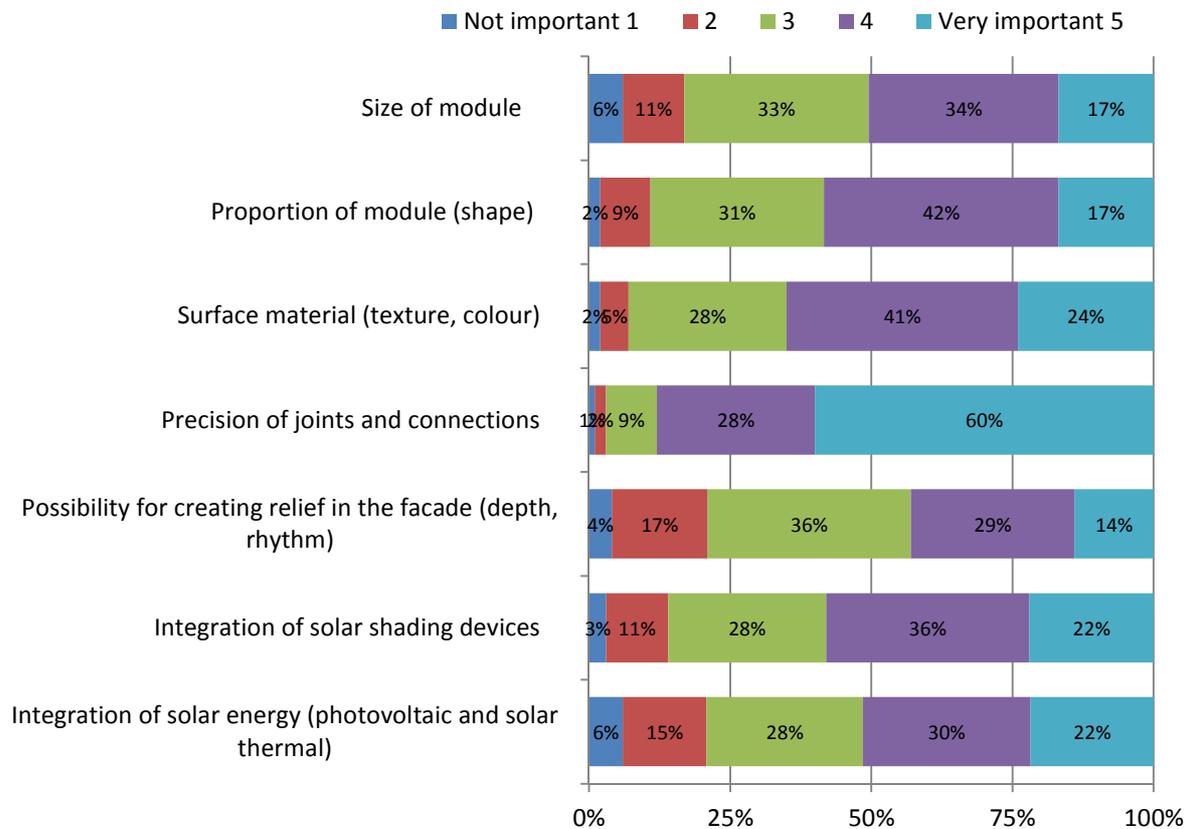


Figure 5 With regard to flexibility in architectural design, rate the importance of the aspects from 1 (not important) to 5 (very important).

The final question of the questionnaire provided respondents with the opportunity to elaborate freely upon the questions previously asked by summarising what they personally prioritise in retrofit design. A total of 176 responses were received and analysed. However when evaluating the open answers we have chosen to focus on the answers from the countries where there was the greatest number of responses, Norway, Germany and Spain. 38 respondents from Norway provided comments, 29 from Germany and 45 from Spain.

Out of these responses, seven basic areas of focus were identified; energy efficiency, cost, ease of application, flexibility, maintaining existing integrity of the architecture, improvement of the aesthetic quality and user comfort. Interest in the seven areas of focus varied dependent on the country answering. This difference was determined by evaluating the relative number of responses which were counted across the seven topics of interest within each of the three countries. Amongst the responses the most referenced element in good retrofitted design was energy efficiency. Cost was noted as the next most important and aesthetics (architectural expression and design) as the third most important.

Amongst the **Norwegian** open answers several respondents point out that more than one consideration is important when considering retrofitting. For example a respondent from a Norwegian housing cooperative states that there is a need for a "*combination of several*



requirements, e.g. the need for facade rehabilitation, balconies, ventilation, repairing moisture damage etc. combined with energy-related upgrades, improved comfort, architectural lift etc. It is important that the process is good, fast and efficient. The residents should have acceptable living conditions or be offered good temporary solutions if they have to move out. Good financial management and control of progress and good calculations when it comes to finances and effects (energy saving etc.)." Within the terminology used by respondents there is a focus on certain words or phrases. Energy efficiency is a central consideration. Within the 38 open answers 14 suggested that energy efficiency was an important consideration, but it was rarely the only factor considered. For example a materials producer suggests that "*good energy efficiency, good layout, more space, better utilization and renewal*" are important factors. Other factors which are mentioned are cost (8 respondents), aesthetic quality (7 respondents) and easy maintenance (5 respondents).

Amongst the 29 open answers from **German** respondents 7 showed an interest in preserving the original appearance of the building is an important consideration, for example a respondent stated that "*preserving the original character and appearance of the building with additional modern design components if allowed*". Only 2 of the Norwegian respondents commented on conservation issues. In addition 7 respondents mentioned that the architectural or visual quality of the building was also important. 14 of the 29 open answers from German respondents show a marked interest in the visual appearance of the buildings being retrofitted. 7 respondents commented on the importance of keeping costs down and 6 stated that energy efficiency was an important consideration. Aesthetic issues appear therefore to be more important in Germany than energy efficiency. Another term which is referred to by the German respondents is technology.

The cost of implementing a deep retrofit is the primary consideration among **Spanish** respondents. 25 of the 45 respondents mentioned cost in their open comments. Energy efficiency is a common requirement amongst Spanish respondents, when considering retrofitting. 19 respondents suggested that this was an important consideration. A Spanish architect suggests that a good project has "*sufficient sensibility to highlight and protect the elements which need to be kept and which take into account energy efficiency.*" Aesthetic quality is an important aspect, 14 respondents mentioned design, architecture, conservation or the visual appearance of the building as being important qualities in retrofitting. User comfort or requirements is an aspect which Spanish respondents focus on but which is not primary for Norwegian or German respondents. 14 respondents mentioned usability, user needs or comfort in their open answers. As is the case in the Norwegian and German responses, the majority of answers combine a number of aspects when aiming at a good retrofitting process "*functional design for users. Reduction in energy demand. A rigorous technical and economic study but one which is understandable to users.*" An efficient process was mentioned by 7 Spanish respondents as being important.

Conclusions

The main finding from the questionnaire survey is that the stakeholders evaluated practical and functional aspects (energy efficiency, cost, construction) of retrofitting with modular elements more important than aspects related to aesthetics, freedom in design and resident needs. This was rather surprising given the great number of architects answering the questionnaire (figure1). Even so, aesthetics scored higher in the open questions than in the closed questions. The main findings are structured by the themes of the questionnaire itself in the following presentation.

On informants and regulations for retrofitting

- The stakeholders that responded to the survey have more knowledge than practical experience with ambitious retrofitting.
- The majority of the stakeholders have little experience in using prefabricated modules in retrofitting.
- More than half of the respondents are not fully aware of the regulation requirements for retrofitting in their country.
- Incompleteness was reported as the greatest weakness associated with the regulations for retrofitting and a generally negative response was documented among the respondents of frustration, confusion and inefficiency.

On choosing prefabricated modules

- *Thermal performance, Robust and low maintenance needs and Quality of craftsmanship* are the three most important criteria when choosing a particular prefab module system. *Freedom in architectural expression, Renewable energy production integrated in the prefab module and Ventilation integrated in the prefab module* were rated as the least important qualities of all listed qualities to be rated.
- The advantages of retrofitting with prefabricated modules according to the survey lie primarily within the practical implementation of a retrofitting project. Respondents suggest that retrofitting with prefab modules will encourage *Efficient construction*, make it *Easier to secure a dry building* and cause *Fewer building defects*. *Improved built quality* also scores high as an advantage with prefabricated modules. In addition, 72% of respondents believe that retrofitting with prefabricated modules will cause less disruption for residents during the rehabilitation process.
- When asked about the pitfalls associated with retrofitting with prefabricated modules *limited architectural freedom* was regarded as the greatest of all pitfalls. *Cost* was regarded as the second greatest pitfall (expensive) and the informants also suggested that retrofitting with prefabricated modules would result in *poor architecture* as the third greatest pitfall.

On architectural requirements

- The five most important architectural requirements a prefabricated retrofit solution have to meet to be an attractive alternative are (after importance): Energy performance, Adaptability to the building, Efficient construction, Flexibility in design (room for tailoring) and lastly Adaptability to the residents' needs.
- With regard to flexibility in architectural design *Precision of joints and connections* are most important followed by *Surface material (texture, colour)* and *Proportion of module (shape)*.



- Amongst the responses in the open question on characteristics of good retrofit design the most referenced element was energy efficiency. Cost was noted as the next most important and aesthetics (architectural expression and design) as the third most important. However it is important to note that the focus on the three most referenced elements varied between Norway, Germany and Spain. Amongst the German respondents there is marked interest in visual or aesthetic qualities, whilst there is less interest in energy efficiency. In Norway the opposite was the case, there was more interest in energy efficiency than there was in aesthetic qualities. The severe financial crisis may explain the strong focus on cost in Spain. It is possible that the difference in focus is not a basic cultural difference, but is due to the role of stakeholders who have answered the questionnaire. For example a greater number of architects answered the questionnaire in Germany than in Norway.

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Reshaping housing using prefabricated systems

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Abstract: Prefabricated housing innovations have the potential to reduce the environmental impact of construction through improvements to efficiency and quality. The current paper presents a number of recommendations for increasing the adoption of prefabrication based on a review of published evidence. The recommendations consider multiple stakeholders including builders and other intermediaries, suppliers, end-users, as well as their interaction with the broader policy context and technical issues.

Prefabricated, modular, housing, policy, review

Introduction

Prefabricated housing is defined as the manufacture of whole houses or significant components offsite in a factory setting. Prefabrication is a promising innovation that encourages repetitive, efficient building processes; accumulation of business knowledge, and addresses the significant environmental impact of new residential building [1]. Traditional, onsite housing construction methods are not efficient and are likely to hamper the future success of the housing industry [2]. The current paper draws on a recently completed literature review to outline a number of evidence-based recommendations on how best to improve prefabrication adoption.

Theoretical model

An ‘open innovation system’ [3] framework was used to guide the review, conceptualising the adoption of prefabricated housing as influenced by a range of interacting stakeholders and contextual factors. An adaption of Gann and Salter’s Project-based Product Framework [4] (Figure 1) was used as the basis for examining this system. This model includes the traditional supply chain from material suppliers, to intermediaries using these materials to assemble prefabricated housing, to individual or developer ‘users’ commissioning housing. The supply chain operates in a context where regulations, relevant institutions and technical issues influence their activities.

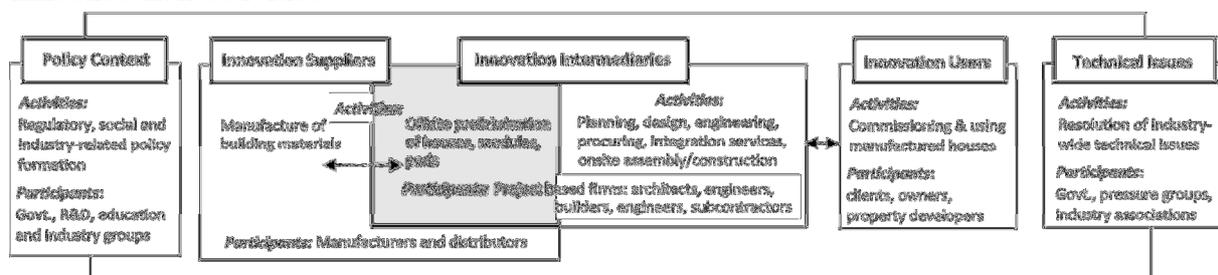


Figure 1. Prefabricated Housing Innovation System

Method

This paper presents a number of recommendations stemming from a recently conducted *systematic review of published evidence regarding the barriers and drivers to the adoption of prefabricated housing* [5]. The review was primarily conducted using the Compendex abstract database, which indexes over 9 million articles from engineering publications including those related to construction, the built environment and housing. The search scope was limited to articles published since 1990, using variations on key terms such as ‘prefabricated’, ‘modular’, ‘offsite’, ‘manufactured’ and ‘industrialised’ in combination with the stem ‘hous*’ (e.g. house, houses, housing) or ‘home/s.’ The results were supplemented with searches through Google and Google Scholar. A total of 185 relevant publications were reviewed.

Scope

The recommendations focus on prefabrication’s application to the permanent housing market including detached houses, townhouses and apartment blocks and excluding temporary or mobile structures. Prefabrication can be represented as a continuum from houses wholly completed offsite to the use of lower-order component materials [6] (Figure 2). All forms of prefabrication from panels to complete houses (Levels 3-6) are considered in scope for the current paper.

1. Materials	2. Components	3. Panels	4. Pods	5. Modular	6. Complete
Standard building materials (<i>timber, bricks</i>)	Low level pre-cut or assembled components (<i>trusses, doors</i>)	Structural elements defining space (<i>wall panel</i>)	Volumetric units added to existing structure (<i>bathroom pod</i>)	Volumetric units, joined onsite to form house (<i>part-house</i>)	Whole houses including multiple rooms and fittings.

Figure 2. Continuum of prefabricated house construction levels

What are the current challenges?

Suppliers. There has been a lack of research into the role of prefabrication suppliers. The key issue identified is the need to form integrated and mutually beneficial relationships with intermediaries using their products, encompassing sharing of knowledge, development of standardised products and negotiation of the co-dependence of business risk.

Intermediaries. The primary issue for various intermediaries, in particular builders, is a resistance to change from traditional processes. This resistance stems from a variety of valid reasons including the unproven cost benefits of prefabrication, business risks associated with process changes, threats to traditional work methods, and an inability to secure significant revenue streams. These threats are particularly pertinent for smaller businesses that have fewer resources to support the adaptation process. Opposing these threats are the potential improvements in operating costs, efficiency and quality which would reward those businesses successfully able to embrace new prefabricated methods.

Users. Negative consumer perceptions have historically been a significant barrier to developing a larger market for prefabricated housing, and these persist despite not being necessarily representative of the modern industry. Reducing the end cost of purchasing houses has been identified as a major driver that can force end-user reappraisal of prefabrication.



Speculative, short-term housing development models however do not currently encourage prioritisation of prefabrication technologies.

Policy context. Modern macroeconomic conditions have not generally been a fertile base for growing a prefabricated housing industry. The house-as-a-project, end user pays, demand model often used in traditional builds is not well suited to prefabrication's ideal of a factory-based supply model. This raises the question of business viability where significant populations and economies of scale may not exist. An unwillingness of risk-averse banks, financiers and insurers to engage with the prefabrication industry also limits change. There has also been a lack of regulation and policies specifically concerning prefabricated housing, and little rigorous assessment of the few policies instated. In line with builders' focus on cost issues, economic drivers such as offering fee concessions appear to be key immediate influences.

Technical issues. Associated innovations like standardised building components, centralised production, and automation promise greater efficiency and a closer alignment to emerging technologies like Building Information Modelling. These advantages are however offset by the difficulties in maintaining traditional design flexibility and increased logistics associated with the transport of large, volumetric units.

Recommendations to improve prefabrication adoption

There is a continuing need for clearly defined, rigorous research to determine the value, from multiple perspectives, of adopting prefabrication. The following recommendations consider a range of issues and stakeholders across the prefabricated housing innovation system.

Reframing the debate. At a system-wide level, it may not be constructive to present prefabricated housing as a direct competition to tried and tested traditional methods, as this may create the impression of unacceptable risk in a market already resistant to change [7]. Rather, prefabrication should be presented as a complementary, alternative building method that can incrementally offer advantages to the overall housing industry. This soft diplomacy position has been adopted by prefabAUS, the peak Australian body for prefabrication [8].

Recommendation 1: Academic reframing of the debate around prefabricated housing should not engage in divisive statements that present prefabrication successes as happening at traditional building's expense

While prefabrication advocates should stay true to their ultimate goal of widespread adoption and abandoning of inefficient traditional methods, they should accept that changing ingrained, society-wide behaviours is a slow process consisting of many milestones. This is analogous to the harm-minimisation approach used in many health-based policies, where negative behaviours are accepted as inevitable, resulting from complex influences, and any positive change is applauded as progress towards the goal [9].

Restructuring traditional processes. The necessary restructuring of traditional builder and supplier methods of working, both independently and together, highlights the need to further understand *how* the house building industry will transition. It is likely the industry will embrace prefabricated housing incrementally. Over-emphasising the traditional nature of house building may result in hesitation towards the first steps to improvement. Further

investigation is required into how disruptive or easily adopted particular innovations are, rather than broadly considering prefabricated and traditional build methods as irreconcilable, polar opposites [10, 11]. Subtle differences in perceptions towards prefabrication are likely dependent on specific contractor roles. While architects' negative views may arise from a reduced design role, engineers and builders may have a greater focus on the perceived technical inflexibilities [12]. Wherever possible, self-serving, protectionist opinions from lobby groups or industry bodies should be clearly differentiated from best practice for the housing industry as a whole.

Recommendation 2: The strengths and weaknesses of various prefabrication innovations should be profiled and matched to the respective strengths and weaknesses of a range of industry stakeholders

Best practice management approaches to allay the impact of work process changes, and achieve optimum efficiency must also continue to be identified [13]. While business decisions may rest with boards of managers, their long term success hinges on presenting an appealing and viable alternative workplace that could attract skilled employees away from traditional house construction industries.

Recommendation 3: Strategies to attract and retain rank-and-file workers to the prefabricated housing industry must be formulated

Better assessment of value. Given the strong impact of basic economic drivers on the housing industry, further empirical evidence is required into the costings of specific prefabricated housing innovations. Cherry-picked costing figures in isolation do not adequately represent the benefits and costs of varying construction methods. For example, a study of bespoke detached housing in sub-tropical Australia found that the total cost of designing and constructing a house can be difficult to determine for comparative purposes because costs are incurred at various stages of design and construction, are payable to multiple supply chain agents, and there is no common standard for determining the scope of which costs are included in a recognised house price [14]. Such comparisons would benefit from a detailed breakdown presenting the costs of physical materials, labour costs, costs due to delays; or from a planning perspective, the certainty of costs at the time of contract signing, and the variability of costs during the build process [15]. Such informed, accurate decision making is central to practical economic policy development.

Recommendation 4: A validated pro-forma assessment tool should be developed and applied to assessing the range of costs prefabricated housing businesses may incur

Such a tool should take into account both the immediate build process and the context in which it was conducted. Further understanding of the housing market segments where prefabrication would be most likely to succeed is also needed [16]. The viability of prefabrication companies has been noted as being strengthened by being able to target particular segments of the market, such as low-cost housing, extensions, remote housing, or the export market [16, 17].

Recommendation 5: The applicability and opportunity for success of prefabrication in varying housing segments should be analysed, taking into account the local market context



A compilation of this data would additionally serve to identify exactly where future research and development investment should be directed.

Understanding the consumer perspective. It has been argued that there has been an undue focus on the build process, rather than on determining how best to meet consumer demands using prefabrication methods [18]. It is largely unknown to what degree the house-purchasing public will accept limitations on the flexibility of housing designs as a trade-off against other potential benefits [19, 20]. More sophisticated examination of costs beyond the purchase price is required, to consider certainty of costs, maintenance costs and living expenses post-occupation [21]. Indeed, what constitutes value for a consumer, such as low whole-of-life cost and design input, may differ substantially from a builders' emphasis on efficiency and profitability [22]. More effort and research is required to specifically understand the nuanced perspective of consumers regarding prefabricated housing [23].

Recommendation 6: Widespread surveying should be undertaken to quantify consumer preferences towards modern traditional and prefabricated housing

Preferably, this should be conducted using blind testing focused on quantifying the importance of various factors, without explicitly mentioning loaded terms such as 'prefabrication' in recruiting participants.

Monitoring the changing policy context. While costs were noted as a central consideration for both builders and consumers, Blismas et al [24] suggests that greater consideration should be paid to other non-monetary factors. Goulding et al [25] outlined a number of future research priorities for prefabrication including understanding socioeconomic drivers, and considering how prefabrication processes work alongside existing or proposed standards and legislation [25]. In many countries such as Australia, there is a lack of clear evidence about the state of the prefabricated housing industry, and how it has varied in relation to changing circumstances. Other countries such as Japan maintain statistics about the proportion of houses that are prefabricated which can be used to identify trends [26]. The ability to measure progress in shifting to prefabrication is also key. Without clearly defined assessment tools that target observable and measurable outcomes, clear policy guidance is unlikely [27].

Recommendation 7: Measures of the prevalence of prefabrication should be developed, and regularly collated and shared with relevant stakeholders

Many jurisdictions likewise suffer from a policy black hole regarding prefabrication that suggest it is not considered as a serious alternative. Formal policies are unlikely to be developed without an initial impetus for change, which may come in the form of small example projects supported financially by government funds.

Recommendation 8: Small-scale grants to develop pilot prefabricated housing projects should be offered that would serve as a test case for the development of policies and a showcase of potential

Standardising to solve technical problems. Building Information Modelling's influence on the construction industry is growing [28]. Its imposition of structure, order and pre-planning to construction projects fits well with the standardisation promoted by prefabrication. Industry members should seek to align themselves with this modern progression to standardisation.



With greater standardisation there is a reduced need for individual businesses to redundantly solve technical problems such as those relating to design flexibility or transport.

Recommendation 9: A coalition of builders, architects, transport businesses and other technical stakeholders should be brought together to draft a set of open specifications for particular components such as structural panels or modules that would encourage interoperability, and drive industry-wide competition and innovation [29, 30].

Common sizings, materials and connections would all contribute to greater overall efficiency in the network of prefabricated stakeholders. Such a process should however not dictate processes such as automation, but rather broadly define the nature of products produced and how they interoperate. This would ensure that a network of service providers could support one another and develop a stronger prefabricated housing industry overall.

Conclusion

This paper has drawn on the body of existing published evidence to present a coherent set of recommendations for improving prefabricated housing adoption, based on a clear theoretical model. The recommendations include changing the discourse surrounding prefabrication, better assessing the current state of the industry, identifying opportunities, and investing in the support of early innovators. There are roles for engineers to tackle technical build limitations, architects to create compelling and flexible designs, economists to determine whole-life cost implications, builders to experiment with new methods, social researchers to identify and change perceptions, and governments to provide high-level industry support. Opportunities exist to introduce real change in housing through prefabrication, and a distributed network of actors rather than any single party is necessary for driving these changes.

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Session 85:

Which are the key elements to follow-up environmental targets at an urban scale?

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Impact Assessment and Life Cycle improving energy efficiency in urban areas

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Abstract: *With increasing importance in urban sustainability, the improvement of the environmental performance of urban areas requires mathematical models able to integrate the different aspects of each system that constitute them from a life cycle perspective. A simplified method that uses the life cycle assessment (LCA) methodology is proposed in this paper in order to analyse the impact assessment improving energy efficiency in urban areas, including the main alternatives for water and waste water treatment, electricity/fuel supply including heating and cooling equipment of buildings, public lighting, the citizens' mobility, the architectural design of buildings, green areas and the waste management techniques. The aim is to compare the environmental performance of selected solutions considering its production, use, maintenance and end-of-life stages. Thus, the proposed methodology allows assessing the sustainability level of different types of urban areas considering their life cycle, and establishing scientific criteria for the design and planning of eco-cities.*

Keywords: *Urban areas, life cycle assessment, eco-efficiency, energy savings*

Introduction

Urban areas have become one of the most intensive sectors in the use of energy and raw materials. According Eurostat, in 2011, approximately 41% of the population of the EU27 lived in urban areas. Urban areas are characterized by the demand of the necessary infrastructure for urban mobility (streets and roads), water supply, sewerage, waste management, electricity, gas, etc., involving a considerable land occupation. The United Nations Environment Programme (UNEP) identifies five key infrastructure areas for achieving resource efficient urban areas: (i) building energy efficiency, (ii) waste management, (iii) sustainable urban transport, (iv) water/wastewater, and (v) urban ecosystem management; also remarks the importance of an integrated analysis between sectors within the assessment of their environmental implications [1]. These infrastructure areas are related to the durability of their buildings, which also requires prior land development, e.g. at an urban level, the generation of Municipal Solid Waste (MSW) and construction and demolition waste (CDW) is mostly related to the life-cycle of buildings. In this sense, the improvement

of the environmental performance of urban areas requires mathematical models able to integrate the different aspects of each system from a life cycle point of view. Thus, the Life Cycle Assessment (LCA) methodology provides better decision support when optimising environmentally favourable design solutions that consider the impacts caused during the entire lifetime of buildings [2], urban water systems [3], urban waste water systems [4], district energy systems [5], urban energy lifecycle [6], lighting technologies [7], earthwork activities [8], waste management systems [9], urban mobility [10], green areas [11] and urban areas [12].

Some methodologies and tools exist for assessing different aspects of the environmental impact of urban areas. On the one hand, a greenhouse gas (GHG) accounting protocol has been developed recently; this is the PAS 2070:2013 – Specification for the assessment of GHG emissions of a city by direct plus supply chain, and consumption-based approaches [13]. PAS 2070 specifies requirements for the assessment of GHG emissions of a city or an urban area following two methodologies: direct plus supply chain (DPSC) methodology and consumption-based (CB) methodology. It includes 6 different GHG emission sources categories: (i) stationary – fuel combustion in buildings and facilities and or energy generation, (ii) mobile – fuel combustion for transport, (iii) industrial processes and product use (IPPU), (iv) Agriculture, forestry and other land uses (AFOLU), (v) waste and wastewater treatment and (vi) goods and services – water provision, food and drink and construction materials. On the other hand, Neighbourhood Evaluation for Sustainable Territories (NEST) is a supporting tool which allows a quantitative estimation of urban projects environmental impacts, since the sketch stage of the project. It relies on the LCA methodology to assess the environmental impacts of the neighbourhood under study. The system considered in the NEST tool is the whole neighbourhood (in terms of geographical scale). Within the tool, the system is defined by the following characteristics: the implantation site (location), the number, size and types of buildings, public spaces, green spaces, roads and parking [14].

Since NEST tool only considers some aspects or key infrastructure areas for achieving resource efficient urban areas and in some of them only considers the materials and energy flows regardless their lifecycle, there is a need to a wider application of the LCA methodology for the assessment of the environmental implications of urban areas ensuring an effectively improvement of their life cycle energy efficiency and also bringing this methodology closer to a broad public not necessarily familiar or specialist in LCA. In this sense, on the framework of UrBiLCA project, a simplified method that uses the LCA methodology is proposed in this paper in order to analyse the impact assessment improving energy efficiency in urban areas, including the main alternatives for (i) water and waste water treatment, (ii) electricity/fuel supply and generation, including heating and cooling equipment of buildings, (iii) public lighting, (iv) the citizens' mobility, (v) the architectural design of buildings, (vi) green areas and (vii) MSW and CDW management.

The UrBiLCA project

The “UrbiLCA project –Assessing the life cycle impact and improving energy efficiency in urban areas”, co-financed by the European Regional Development Fund (ERDF) – SUDOE Interreg IV B, started in January 2013 and will run until December 2014. It aims to promote

energy savings, efficient use of raw materials and the reduction of the environmental impacts of the management of urban areas during its construction, operation and maintenance, and end-of-life, as well as promoting the use of LCA as evaluation technique during the design and planning of new urban areas and the rehabilitation or retrofitting of existing ones. From the scientific point of view, one of the main project milestones is the development of mathematical models of processes and associated infrastructure to the life cycle of urban areas, including the main alternatives for the provision of water, electricity and fuels, user's mobility, the architectural design of buildings and equipment, and the collection and treatment of MSW and CDW.

The UrbiLCA project is the capitalization of the products and results of the EnerBuiLCA project "Life Cycle Assessment for Energy Efficiency in Buildings"¹ which is part of the Interreg IV - B SUDOE Programme. In the course of the EnerBuiLCA project, which concluded in December of 2012, it has developed a database of environmental impacts of construction products from the SUDOE region, a LCA tool in buildings, as well as an on-line thematic platform of LCA. As regards of the development of the LCA tool, it has identified the necessity to expand its spatial scale by extending the system boundaries of the buildings to urban areas.

Methodology

The LCA methodology is used to evaluate the environmental impacts of each of the stages under consideration. This provides a structured analysis of inputs and outputs at each stage of the life cycle of products and services [15]. ISO 14040:2006 [16] prescribes the clear definition of the goal and scope of all LCA studies including the system boundary, the functional unit and the inventory analysis by means of data collection within the system boundary. The assessment process is divided into four basic steps: (1) defining the goal and scope of the analysis; (2) inventory analysis; (3) impact assessment; and (4) interpretation. Assessment is performed on the entire life cycle of the process or activity, including the extraction and processing of raw materials, manufacturing, transportation, distribution, use, recycling, reuse, and final disposal.

Goal and scope definition. The main objective is to compare the environmental performance of selected systems in urban areas considering its production, construction, use and end-of-life stages. The functional unit is the unit of reference for all the inputs and outputs of the system to be obtained from Inventory Analysis [17]. When applying LCA at urban level, defining a functional unit is a complex task as urban areas includes several systems and infrastructures. It is even more complex to define a generic functional unit. In this sense, the following functional units have been defined in the methodology:

- Buildings: the building itself is selected as functional unit, considering its life span. In order to simplify the characterization of buildings in an urban area, it will be selected a set of representative buildings based on the EnerBuiLCA tool.

¹ EnerBuiLCA Project. funded through the Interreg IV B programme, started in March 2011 and will run until December 2012: (www.enerbuilca-sudoe.eu/)

- Water and wastewater: distribution and treatment of water to supply 1 m³ of water to the inhabitants of the urban area. In case of the rainwater a 1 m³ of rainwater managed is considered.
- Street lighting installations: provision of lighting and distribution of electricity to supply 1 lumen.hour/m² of an urban area.
- Generation of district heating, cooling and distribution system: supply the user of an urban area of 1 MJ (or kWh) of energy for heating or cooling
- Earthworks and earthmoving: transport of 1 ton of ground
- MSW and CDW management: 1 ton of MSW and CDW collected and treated
- Urban mobility: 1 passenger * km
- Green areas: 1 m² of green areas

The LCA of these different systems is based on the weighted aggregation of the respective LCAs of their various components and subcomponents.

Target areas and quality data.

In order to validate the method proposed, 6 case studies in different regions of Spain, France and Portugal are used:

- Case study 1 - Ecocity Valdespartera – Localisation: Zaragoza (Spain).
- Case study 2 - Txomin Enea - Localisation: Donostia/San Sebastián (Spain).
- Case study 3 - Eco-quartier du Maharin - Localisation: Anglet (France).
- Case study 4 - Eco-hameau - Localisation: Andernos-Les-Bains (France).
- Case study 5- Parque das Nações - Localisation: Lisbon (Portugal).
- Case study 6- Alto dos Moinhos - Localisation: Lisbon (Portugal).

System description and boundaries of the system

Based on the life cycle stages of a building presented on CEN/TC 350 standard, EN 15643-2 [18], the systems and stages considered in the proposed simplified methodology are presented below:

I. Product Stage

The list of urban modules to be evaluated in the UrbiLCA project, 8 in total, and the list of systems and infrastructure associated with each module are presented as follows:

Buildings

- a) Processes associated to the supply of raw materials
- b) Transport up to the factory gate
- c) Manufacturing processes for the construction products, including the processing of any waste arising from these processes.

Waste treatment infrastructure

- a) MSW
 - i. Collection and transport systems
 - Conventional systems for collection and transportation of MSW
 - Pneumatic systems for collection and transportation of MSW
- b) CDW
 - i. Collection and transport systems
 - Conventional systems for collection and transportation of CDW

Water cycle infrastructures

- a) water consumed and treated
 - i. Supply
 - Distribution systems in the urban area:
Pipes (cement / casting / PVC / polyethylene / ceramic / steel) and Pumps
 - ii. Sanitation
 - Sewage collection systems
Pipes (cement / PVC)
 - Pre-treatment in-situ and treatment of grouped domestic sewage
 - Rainwater collection systems
 - Greywater recycling systems
- b) Rainwater collected and treated
 - i. Pipes
 - ii. Storage structure and rainwater drainage (excluding driveway)
 - iii. Drainage
 - iv. Infiltration wells
 - v. Retention basins
 - vi. Retention basins / infiltration areas
 - vii. Phytodepuration systems

Roads and infrastructure for urban mobility

- a) Vials and surface parking areas (m²)
- b) Cycle routes



Installations for air conditioning and district electrical / thermal energy production

- a) Electric power
 - i. Generation Systems - within urban area limits. At the building level they are included in EnerBuiLCA tool.
 - ii. Photovoltaic systems
 - iii. Micro - turbines
 - iv. Trigeneration
- b) Thermal energy
 - i. Heating and cooling district systems
 - Geothermal heat pumps
 - Chiller : centralized ventilation systems and air conditioning
 - Boilers (single or double function)
 - Electric thermal storage
 - Solar thermal collectors
 - Trigeneration
 - ii. Heat and cold distribution systems
 - Gas pipes
 - Storage tanks
 - Heating and cooling networks

Urban street lighting systems

- a) Lamps
 - i. Fluorescent
 - ii. High intensity discharge (mercury vapour, high-pressure sodium vapour, metal halide)
 - iii. LEDs
 - iv. Magnetic induction
- b) Luminaires (vials, residential, ornamental)
 - i. Luminaire structure
- c) Holding devices
 - i. Column
 - ii. Crosier

Green areas

- a) Lawn
- b) Green roof /wall
- c) Trees in mineral area

For each urban module, the environmental impacts of the production of the elements that form the infrastructure are considered. Those elements are included within the perimeter of the urban area (e.g. pipes, containers, lighting). In this sense, a database associated with the environmental impact information (primary energy consumption and CO₂ equivalent emissions), lifetime and mass for each system listed above is used. This aggregate data represents all infrastructure elements that constitute the whole system. Finally, the module



on earthworks is not included in this stage since it is not associated to an infrastructure. At this stage, only the impacts of the production of the infrastructure are included in the scope of the urban area.

II. Construction process stage

The construction process stage for buildings is already considered in the building module of the EnerBuiLCA tool. For the rest of modules, the environmental impacts of the construction phase are neglected except for those associated with the consumption of fuel and electricity for heavy machinery used in earthworks and earthmoving during the construction process of all modules considered.

III. Use stage

In the use phase of the urban area, the environmental impacts related to the following aspects are included:

- The MSW management, considering the amount of MSW generated in the urban area. Also, it will include a treatment and disposal scenario for each region studied.
- The distribution and treatment of drinking water and the collection and treatment of rainwater.
- The use of vehicles.
- The distribution of electricity in the urban area and the generation and distribution of heat and cold.
- The benefits of the atmospheric CO₂ fixation in the green areas.

The impacts related to maintenance of infrastructure are not included in the use phase. In contrast, the environmental impacts of substitution infrastructure's elements of the modules considered (except for earthworks) are included, also considering their life span.

For the operational energy consumption, the fuel and electricity consumption will be considered taking into account the following aspects:

- MSW transport and treatment
- Water pumping and distribution
- Energy consumption for urban mobility
- Electric and thermal energy distribution
- Street lighting
- Machinery used for site preparation and earthworks and green areas

The operational energy consumption for heating, cooling and domestic hot water in the building is already considered in the building module of the EnerBuiLCA tool. Finally, the use of operational water includes the water consumption associated with the treatment of waste, distribution losses of water and the process of generation of thermal energy and the maintenance of green areas expressed in litres per year.



IV. End-of-life stage

The environmental impacts of transport will be included at the end-of-life stage including the treatment of CDW in all modules. As a general rule, the amount of input raw materials in the production phase will be considered as the amount of CDW. Additionally, the impacts of processing and treatment of CDW is specified to each region of SUDOIE.

Life Cycle Impact Assessment

The environmental impacts will be determined from a midpoint-level approach. Taking into account the phases of the impact assessment (classification, characterisation, normalisation, and weighting) at the midpoint level, the potential environmental impact of the Life Cycle Inventory (LCI) are those presented in the IPCC 2007 GWP 100a V1.02 impact assessment method [19], which summarises the GHG emissions in terms of CO₂ equivalent emissions. Additionally, the Cumulative Energy Demand (CED) method V1.08 will be used to calculate the total embodied primary energy of the systems studied measured as MJ-equivalents [20].

The UrBiLCA tool

An user friendly tool for the quantitative assessment of direct and indirect energy related impacts of urban areas in Spain, the South of France and Portugal (SUDOIE area) is on developing based on the proposed simplified method in this paper. The scope of the EnerBuiLCA tool is extended to include the end-of-life of the buildings and infrastructures related to systems considered. Thus, the processes of deconstruction, demolition, waste collection and their subsequent transport and treatment, are included in the tool. In this sense, the tool will allow the development of the appropriate strategies for reducing energy related impacts throughout the urban area's life cycle, from materials production, building and infrastructure construction, use and maintenance to building refurbishment and end-of-life. The technical specifications of the tool are the same as those presented in the EnerBuiLCA tool for buildings. It will measure the primary energy consumption and the associated CO₂ equivalent emissions to the life cycle of an urban area. To evaluate urban areas it will be included the new specifications listed below:

1. Expanding the EnerBuiLCA data base with impact information of the systems and production processes of the infrastructure elements specified in the system description.
2. The inclusion of water consumption as new impact category in the use phase of the building and urban area.
3. The creation of a calculation module for comparing reference scenarios at building and urban area level.

Expected results and conclusions

The results will allow assessing the sustainability level of different types of urban areas considering all the stages of their life cycle, and establishing scientific criteria for the design and planning of eco-cities, promoting integration and use of Best Available Techniques (BAT) in several processes and urban infrastructures. Besides, information and new scientific



knowledge will be obtained in order to make recommendations for policy makers related to the reduction of environmental impact in urban areas and to improve the present national legislative framework or to suggest new legislative requirements. The project will provide a software tool for incorporating environmental information and the application of the LCA methodology in the design, construction and/or rehabilitation of urban areas. Finally, the results may be used by real estate companies and the inhabitants themselves when evaluating their purchase-sale or rent, as well as by public authorities in defining sustainability policies for municipalities.

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Design and operation of a test bench for Agent based control systems of building supply systems

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Abstract Summary:

Complex modern building supply systems often lack well functioning control systems. Usually, this leads to inefficient operation modes and poor user comfort.

The use of Multi-Agent-Systems (MAS) can help to create self-organizing structures, which are able to find suitable operating conditions in an automated way. In order to use MAS for building systems, every component has to be equipped with a single decentralized control unit (Agent). These Agents have information about corresponding consumer demand or supply unit potential. Furthermore, every Agent has an individual cost function for either supply (generation costs) or demand (comfort costs). The Agents are able to negotiate with each other in order to determine the cheapest and therefore most efficient way of meeting the requirements of the building.

This paper presents a setup for a test bench of MAS-control for building systems. First results show the basic functionality of the implemented system and the impact of different cost functions.

Keywords: Multi-Agent-System, Agent based control, test bench, building control system

Introduction

The actual energy demand of building supply systems for heating, cooling and ventilation often exceeds the forecasted values of energy demand calculation (1). Therefore, poorly configured and implemented building control systems are a main reason for high operating cost of buildings as well as high CO₂-emissions.

Ecological and economical issues as well as legal constraints are leading perpetually to an increased complexity of building supply systems. Different supply units for heating, cooling and ventilation are often combined into one system in order to increase the buildings' energy efficiency (2, 3). This trend strengthens the need for better solutions for building control systems.

Usually, buildings are controlled by a single central control unit (4). These control units have to be set up individually for each building. Furthermore, every time the building configuration changes, the control software has to be adapted as well.

All these facts combined with the necessity to introduce control systems as part of building evaluations (5) illustrate the challenges as well as the importance of well designed building control systems. A possible approach to reduce the individual implementation effort of building control systems as well as to reach well-adapted and self-learning systems, is the use of Multi-Agent-Systems (MAS). Ideally, these systems find their optimal operating point independently regarding appropriate boundary conditions.



MAS have been used in information technology as well as in electrical engineering for decades (6). The use of MAS helps to create self-organizing structures, which are able to find suitable operating conditions in an automated way (7). There are also first case studies for the use of MAS in the building sector, mainly based on simulation (8, 9).

This paper introduces a test setup for MAS systems for building components. Different components for heating, cooling and ventilation have been equipped with software Agents in order to constitute a MAS. The authors show how the MAS is set up theoretically and how the Agents are implemented into real hardware. In addition, first results are presented, which demonstrate the basic functionality of the implemented system and the impact of different cost functions, which are explained in a later chapter.

Multi-Agent-Systems for building supply systems

In industrial automation, Agents are defined as “an encapsulated (hardware/software) entity with specified objectives. An Agent endeavours to reach these objectives through its autonomous behaviour, in interacting with its environment and with other Agents. (...) A multi-Agent system consists of a set of Agents interacting to fulfil one or more tasks. “ (7)

In the building sector, MAS systems can be used in order to coordinate and control the components for ventilation, heating and cooling. Therefore, every component has to be equipped with a single decentralized control unit (Agent). These Agents require information about the individual demands of the corresponding consumers (e.g. energy demand for room heating) or potentials of the corresponding supply units (e.g. available heat performance of heat pumps). Furthermore, every Agent has an individual cost function for either supply (generation costs) or demand (comfort costs). The Agents are interconnected and able to negotiate with each other in order to determine the most efficient way to meet the demands of the building.

The main challenge in creating a MAS for building supply systems is to establish a control architecture with a functional negotiation process. This architecture has to guarantee a stable system. On the other hand, it has to be flexible enough to enable fast and easy system changes, ideally by plug and play of new components.

Test bench for MAS of building supply systems

The experimental setup has been integrated into an existing test facility for building components. The test facility consists of an air handling unit with different heating and cooling devices as well as three identical reference rooms, which are used to provide building loads. In addition, each room is equipped with individual heating and cooling devices. The air handling unit as well as each of the reference rooms are equipped with their own Agents. Figure 1 shows a scheme of the entire test facility.

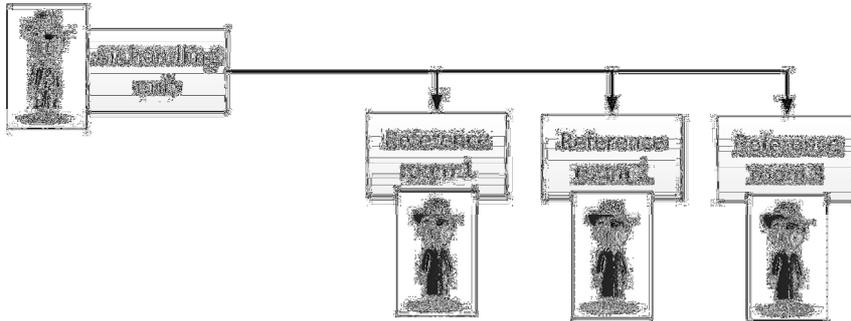


Figure 1: Scheme of the test setup with Agents

The air handling unit itself consists of several components. Each of these components is also equipped with its own Agent. Figure 2 shows a detailed scheme of the air handling unit with the corresponding Agents. These Agents are situated in a sublevel of the air handling unit Agent.

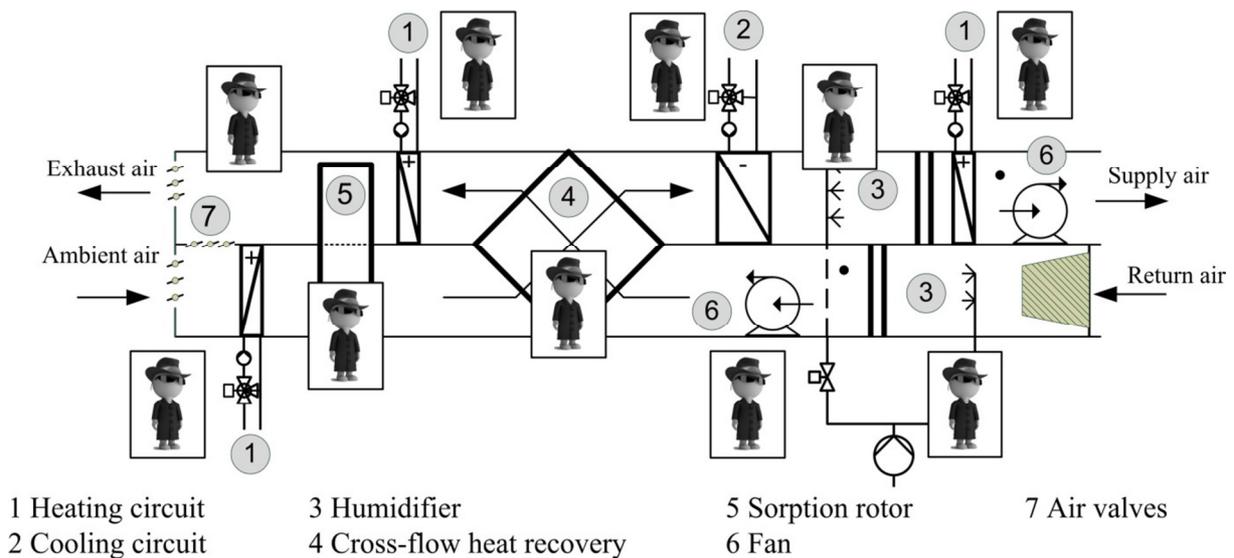


Figure 2: Air handling unit with Agents

Basic architecture of the MAS for building supply systems

In order to find the most efficient operation point, the Agents have to be able to negotiate with each other. Therefore, each Agent knows the cost function of its component to calculate the corresponding performance costs. The cost functions of the supply units are taking into account the real performance costs of the components. For example, the costs of the heater of the air handling unit C_{heater} (€/h) are calculated as follows:

$$C_{Heater} = \dot{Q}_{supply} \cdot c_{supply} + \frac{P_{pump} \cdot c_{el}}{\eta_{pump}} + C_{warmup} + C_{cooldown} \quad \text{in } \text{€/h}$$

First, the amount of required heat performance \dot{Q}_{supply} (kW) has to be estimated. With this value and the specific heat costs c_{supply} (€/kWh), the heat performance costs are computed. In addition, operational costs of the supply pump are computed. The inputs are therefore performance of the pump P_{pump} (kW), electrical tariff c_{el} (€/kWh) and efficiency of the pump

η_{pump} (-). Furthermore, the costs for the warm up of the system C_{warmup} (€/h) as well as for cool down C_{cooldown} (€/h) are considered. These two parameters regard the operation intervals of the heater. If the heater is already in operation, additional power is cheaper than a complete cold start of the system. The cost functions of the other supply Agents are structured similarly. The values for the different parameters have been determined through measurements of the supply system.

In order to decide, whether the reference rooms have to be heated or cooled at all, the room Agents require knowledge of the personal preference of the room occupants, along with a cost function for comfort conditions. For the experiment, these cost functions are based on studies provided by Olli Seppänen (10). This paper deals with the correlation between room comfort and productivity of occupants. Figure 3 shows the relative performance of workers as a function of the actual room temperature.

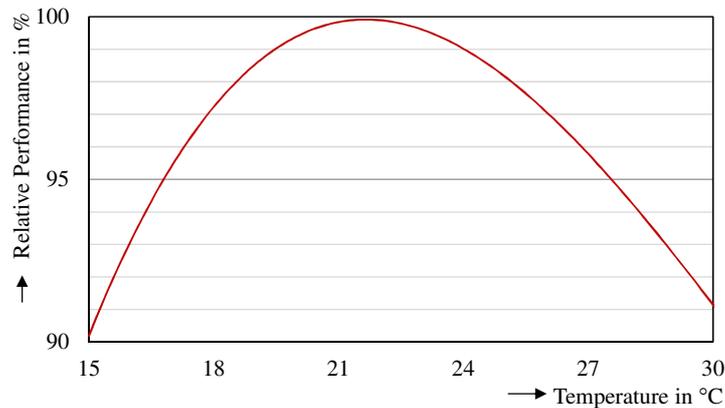


Figure 3: Performance of workers in office rooms depending on the room temperature (10)

The cost of reduced productivity of the occupants at deviating room temperatures C_{occupant} (€/h) can be computed according to formula [2]:

$$C_{\text{occupant}} = (100 - P) \cdot C_w \cdot n_p \quad \text{in €/h}$$

Thereby, P (%) is the current performance level, C_w (€/h) are the average wages of the occupants and n_p the number of occupants. Using this formula, the costs for low comfort can be estimated and compared with the expected heating costs.

Hardware, software and interfaces of the test bench

The described concept is realized by combining different software and hardware platforms. As original control software of the test bench Belimo Shared Logic (SL) is used (11). This platform is based on decentralized controllers. Each of these controllers can be addressed via Ethernet. The actors and sensors are connected to the controllers via MP-Bus-Protocol.

For the implementation of the MAS algorithms Java Agent Development Framework (JADE) is used (12). The behavior of different Agents as well as the Agent architecture are defined within this software.

For the integration of the JADE-parameter into the original Belimo SL software, virtual interfaces are integrated into the Belimo SL in addition to the original control algorithms. These interfaces enable the user to switch between the standard control functionalities and the MAS-control via JADE. The internal control loops of the components (e.g. two-point controller and PID controller) are not influenced by the MAS as the MAS is integrated at a higher control level to set the final activation for the components.

The communication between JADE and Belimo SL is set up via a HTTP-Interface. Figure 4 depicts the interfaces and communicational structure.

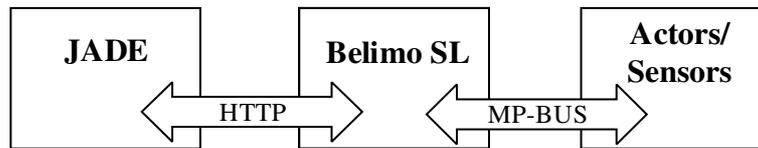


Figure 4: Communication between Agent software JADE, Control Software Belimo SL and components of the test bench

Experimental setup and test scenarios

During the experiments, the set point for the room temperature of each reference room is 24 °C. During the experiment, three different reference rooms have been used in parallel. Within each room, a specified test scenario has been set up:

- Scenario 1: Standard control without implementation of MAS (as reference)
- Scenario 2: MAS-control: Agents apply cost functions including start up costs for the components
- Scenario 3: MAS-control: Agents apply cost functions without start up costs for the components

Results and interpretation

The following diagram (Figure 5) shows the actual room temperature, the temperature set point and the activation of the room internal heating for the three different scenarios. A period of three hours is shown. The thermal behaviors of the three rooms are considered almost identical. The results illustrate the basic functionality of the MAS test bench.

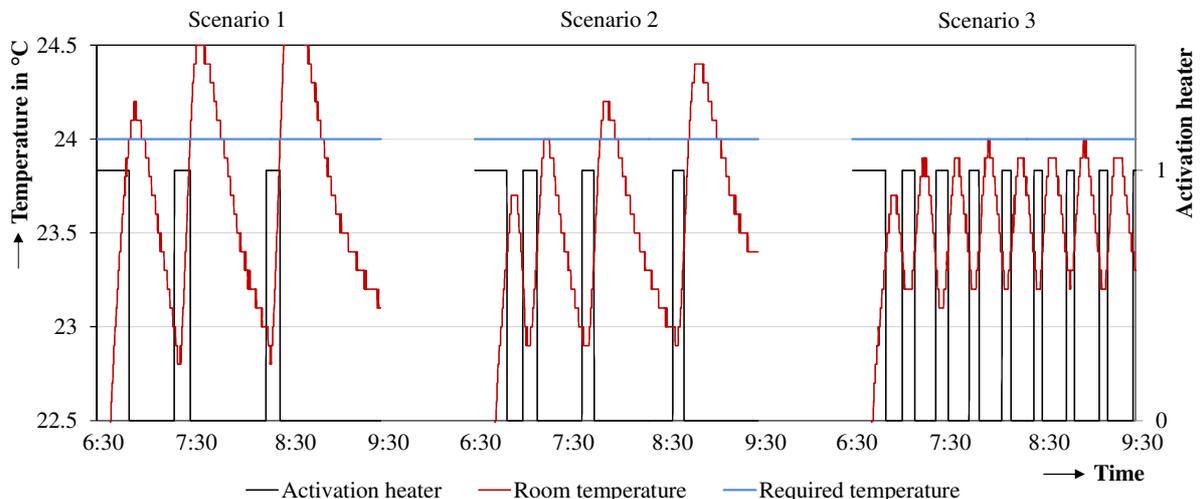




Figure 5: Results of scenario 1 (reference without MAS), scenario 2 (MAS with start up costs) and scenario 3 (MAS without start up costs)

Scenario 1 is the reference scenario without Agent based control. The two-point controller of the room internal controller activates the heater, when the room temperature (RT) is below its set point by more than 1 K. The heater is deactivated, when RT reaches its set point. After that, the room temperature still increases for a while because of the thermal inertia of the heater.

Regarding scenario 2 (MAS with start up costs), it can be seen, that the heater is also activated, when RT drops 1 K below its set point, just like in the reference scenario. However, the heater is turned off, before the set point is reached, because the Agents are comparing the performance costs of the occupants with the potential heating costs. They decide to shut down the heater as comfort-based costs are lower than the costs for the continued operation of the heater. Also in this scenario, the effect of the thermal inertia increases the room temperature after deactivation of the heater.

In scenario 3, the Agents do not consider start up costs. Thus, activation costs of the heater are lower than in scenario 2, which means, the comfort costs exceeds the heater costs at a higher temperature level. However, the heater is deactivated before the set point is reached, because then the performance gain from increased comfort has a lower value than the heating costs. At this scenario, the frequency between activation and deactivation of the heater is quite high, because the cost level of occupants' performance fluctuates around the cost level of the heater, while start up costs, which would function as hysteresis are disabled.

The comparison of the three scenarios shows significant differences. Regarding scenario 2 and scenario 3, the impact of different cost functions of the Agents can be seen. The implementation of adequate cost functions seems to be crucial for the functionality of MAS of building supply systems.

Conclusion and future work

The implementation of the test bench for Multi-Agent-Systems (MAS) for building supply systems has been a first step towards the application of MAS in buildings. The results of the experiments are proving the basic functionality of the used MAS as well as the usability of the experimental set up. The presented example shows, how MAS can be used in order to operate a building supply system according to current demand.

Main obstacles of the test bench are the set up of different cost functions as well as the assignment of the Agents to the components. In order to achieve a MAS fitting to any type of building supply system, self-learning algorithms will be necessary to enable automated configuration of the Agents' parameters. Above that, future research will deal with the optimization of the single Agents as well as the architecture of MAS.



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Energy and architectural retrofitting in the urban context of Athens

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Abstract: *The aim of this paper is to study, evaluate and demonstrate the technical feasibility of nearly zero energy buildings the Athens' urban context. To achieve this purpose, the energy performance of selected typical residential buildings in the urban Athens area have been investigated, in order to properly identify the buildings' energy requirement in winter and summer conditions and finally propose targeted retrofitting hypothesis towards nearly Zero Energy Buildings (nZEBs). The study has been developed on the real case study of a social housing compound of the '60s, with typical structures built by reinforced concrete and infill walls. The setting is located in Peristeri suburbs, in the western Athens Metropolitan Area, which, together with the central Athens, present the highest heat island (HI) intensity of the whole city. Focusing on urban areas, the proposed research considers the buildings and the related space as a whole.*

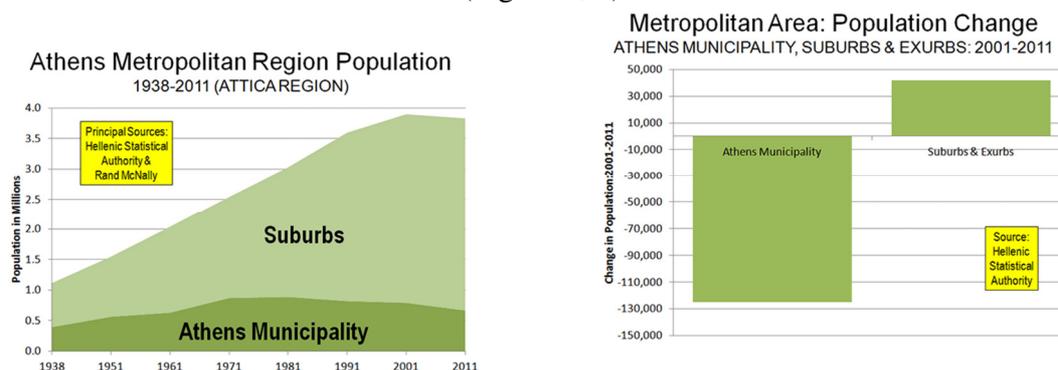
Key words: *Urban context, Zero energy buildings, western Athens metropolitan area, heat island, social housing*

1. State of the art and crucial issues in the urban environment

Cities and their surroundings areas consume the 80% of final energy in EU. Today, more than two thirds of the European population lives in urban areas. Urban growth has reached such a peak, that bypasses, reversals, or new ways of development are needed [1]. Furthermore, many European cities and, in particular, the Mediterranean cities of the EU, are now faced with new and persistent problems of unemployment, poverty and social exclusion, (e)migration. Building deterioration and abandoned areas are predominantly present in many cities of the Mediterranean areas. The growing amount of abandoned urban areas and buildings –including the historical built heritage - represent one of the major hitches throughout the EU cities [2]. Increasing urbanization and deficiencies in development control in the urban environment have important consequences on the environmental and energy efficiency of buildings. [3], [4], [5]. As a consequence of heat balance, air temperatures in densely built urban areas are higher than the temperatures of the surrounding rural zones. The phenomenon, known as 'Heat Island' (HI), is due to many factors [3]: the urban geometry, the thermal properties of materials increasing storage of sensible heat in the fabric of the city, the anthropogenic heat, the urban greenhouse effect.

1.1 Athens Metropolitan Area (AMA)

Athens city area is a metropolitan area (AMA) located at the south end of the Attica peninsula, on the Aegean Sea. Since 1951, suburban and exurban Athens has accounted for 95% of the growth in the metropolitan region, adding 2.2 million new residents, compared to approximately 100,000 for the Athens municipality. Since 1971, all of the population growth has been in the suburbs and exurbs (Figure 1, 2).



Figures 1 and 2: Athens growth population, Source: Wendell Cox, *The Evolving Urban Form: Athens* [6], Principal Source: Hellenic Statistical Authority & Rand McNally

Even with its current slow and even negative growth, the Athens urban area remains among the densest in the developed world. No major urban area in Western Europe, Japan or the New World (Australia, Canada, New Zealand and the United States) is as dense. The [2013 edition](#) of [Demographia World Urban Areas](#) indicates that the Athens urban area has a population of 3.5 million, living in a land area of 225 square miles (580 square kilometres), for a density of 15,600 per square mile (6,000 per square kilometre). This places Athens slightly ahead of London (15,300 per square mile or 5,900 per square kilometre), about double the density of Toronto or Los Angeles and more than four times that of Portland.

The trend towards eradicating the suburbs started in the 70s. There was no "ideal city" image or planning theory that drove the transformation. Most planning efforts were focused on maintaining the strict height limit preserving and enhancing open space and, more intently, on designing and implementing a transportation network that would solve the persistent gridlock. The densification trend sped up in the 80s, and currently continues at the periphery.

Planners despise, deride and deplore the suburbs. Suburbs are depicted as the outsiders of urban evolution, an aberrant, ill-adapted species and the main cause of problems that befall cities and people today such as traffic congestion, poor air quality, environmental degradation, ugliness and even obesity. Their critics recommend a halt to new ones, a retrofit of the existing and putting an end to the idea of the "suburban project" once and for all.

Urbanizing the suburbs, it is argued, would enable city residents to enjoy a better, healthier more fulfilling life in a continuous city that spans an entire urban region. Moreover, the environment will also benefit from reduced travel emissions.

The 20th century brought separation and dispersal of buildings to an extent unparalleled in city history. Aerial photos and ground observation confirm this unambiguously – the sharp contrast of built form between the old "city" and its newer additions is inescapable. However,

the 20th century also ushered a new form of agglutinated settlement, the vertical, elevator block, which can equal several earlier horizontal blocks in habitable space and thus dramatically increase the potential for people concentration. Athens employs all the elements of propinquity and can boast being a contemporary pioneering example of "a city without suburbs" (Figure 3).



Figure 3. Peripheral districts have attained high densities while defying cumbersome topography. Source: Grammenos Fanis (2011).

1.2 Heat Island and climatic aspects in the AMA

Previous studies in the AMA have confirmed the existence of a strong Heat Island (HI) phenomenon [7, 8, 9]. The association of the HI with synoptic climatic conditions have been identified [10], while the influence of the surface temperature and wind conditions have been analysed [11,12]. In parallel, the impact of various mitigation techniques involving cool and reflective materials has been identified [13,14]. All performed research studies on this subject -referring to the 'urban HI intensity' as the maximum temperature difference between the city and the surrounding area- demonstrate that AMA represents a highly significant pilot study: during hot summer seasons (corresponding to the HI upper limit during) urban stations present temperatures significantly higher than the ones recorded in the comparable suburban stations (the gap varies from 5 to 15 °C). A detailed statistical analysis of the heat island characteristics and distribution in the greater Athens area has been carried out [15] using temperature data of 25 stations distributed on the city. Concerning the maximum daily air temperature values, it is found that the differences between the eastern and northern stations during June and July and also between the centre of Athens and the western stations during July were not statistically significant.

As observed, the northern and the eastern parts of the Athens area present a similar temperature regime as a result of the high percentage of green areas and the absence of industrial zone. On the contrary, the centre and the western part of Athens present a similar temperature regime due to the lack of green, the densely built areas and traffic. On the other hand, the study of the mean maximum air temperature values for each month and for all the stations, has concluded that during June higher temperatures are recorded at the centre of Athens and also at the western part, while during July and August the higher temperatures are found at the southern and the western part of the greater Athens area.

The presence of the mountains Egaleo at the western part and Parnitha at the northern part and also of the mountains Penteli and Hymettus at the northern and eastern parts correspondingly

acted as natural obstacles against the north winds which dominate during the summer period at the Athens area (Etesian winds). In the analysis it is concluded that the higher air temperature values were found firstly at the western part, mainly due to the industrialization, and secondly at the center of Athens, due to the traffic and anthropogenic heat, while the lower values were found at the northern and the eastern part of the greater Athens area. According with those results it can be concluded that HI intensity presents its maximum concentration in the center and the western part of Athens area, with up to 5° C. Extremely important conclusions may be drawn from these studies. The geographical position of the Athens area, characterized by the presence of the surrounding height mountains exceeding 1000 m, contributes to the development of high summer air temperatures. High air temperatures are also reinforced by the increased urbanization, industrialization, anthropogenic heat and the lack of vegetation. In particular, during July and August, the mean and maximum air temperatures at the city center and at the western part of the city are much higher than the corresponding values for the northern and north-eastern part of the AMA. Furthermore, from the analysis of the mean diurnal and nocturnal air temperatures in all stations and from the difference between them and the reference station located at the center of Athens, it is possible to conclude that HI during the night period is mainly observed at the western part of the city. For this reason, the present research study has started by investigating an urban compound located in the western part of the AMA.

2. The case study of Peristeri urban compound

Thus, coherently, the research study has been conducted on a case study specifically selected for its representativeness, both in terms of geographical location (the western part of the AMA) and for its constructive type: in fact the building types – a series of block buildings with a structure made of reinforced concrete and infill walls- is massively present throughout AMA suburbs and typically connected with similar building blocks all over Europe, forming, as a whole, the larger majority (about the 60%) of the existing building stock in EU. This percentage even increases (about the 70-75%) if we confine the analysis within the boundaries of the Mediterranean European countries (Greece, Cyprus, Spain, Portugal, etc.) and slightly increases for Italy, as well (about 65%) [2].

To study and evaluate the technical feasibility of nearly zero energy buildings the western part of AMA, the real case study of a social housing compound of the '60s, with typical structures built by reinforced concrete and infill walls has been selected for energy investigation.

Thus, with special reference to the selected case study, the research study has the aim to produce the following achievements:

- i) Evaluation of the energy demand and potential of the urban environment as a significant part of a whole discretized city model based on different urban units, corresponding to the building blocks and the related street/open area as a whole entity.
- ii) Retrofitting actions design towards low carbon urban areas have been hypothesised and validated exploring both passive physical components and energy micro-generating technologies.
- iii) Economical and social feasibility of these actions in localized urban environments to

more easily achieve bottom-up actions driving towards a carbon neutral future.

2.1 The urban compound and the buildings

The area of intervention is in a strategic position in front of the main square of Peristeri, where it is placed the Town Hall and the Metro station. The neighbourhood is degraded and there is a need of a requalification from the energetic point of view that has as an aim to create Zero-Energy performance buildings. The case study consists of a dense social housing urban complex of the '60s, presenting a set of twelve similar residential buildings with different orientation and layouts, marking out this urban compound as the ideal candidate for a sensitivity analysis of energy simulations as a function of the different urban constraints and boundary conditions. Four building types can be identified in the Peristeri social housing urban compound: building "Type A" with two staircases connecting four apartments per floor, "Type B" with three staircases connecting fifteen apartments per floor, "Type T" with a similar structure as type A and the "Tower" a ten floor building, with a main staircase connecting four apartments per floor, (Figures 4, 5).



Figure 4, 5. Peristeri compound presents similar urban buildings with different orientation and layouts.

All buildings have a structure of reinforced concrete and brick walling exterior surfaces treated with plaster. The flat roof and the vertical surfaces are not insulated; the aluminium-framed windows are single glazed and prevalingly equipped with exterior shutters as windows' shading devices. Each building is equipped with a central heating system with cast iron radiators installed in many rooms of the apartments. The majority of residential units are equipped with air conditioning units and some others use solar systems for domestic hot water. Simulations performed have suggested what might be the architectural components and the building sections where to focus in terms of energy retrofitting operations: the roof level, the windows, the facades and the ground floor, thus energy retrofitting scenarios were proposed involving these components: the roof insulation, the green roof, new windows and shadings and combinations in order to achieve the best performance. Furthermore, new facades and a-side additions have been added to the blind buildings' façades, transforming the overall the view of the area and adapting it to the new urban centrality of Peristeri. (Figure 6)



Figure 6. Up, the actual main view of the compound. Down, the proposed additions-transformations to the buildings.

3. Nearly ZEB: an achievable goal

As has been already stated, to minimize energy consumption, careful bioclimatic analysis and consistent design are of strategic importance; if wisely used, they can lead to the construction of totally passive buildings. The technical feasibility of nZEBs in new building constructions can be easily achieved in the Mediterranean climate [16] but existing buildings, and especially the buildings of 60s and 70s, do not respect the rules of the bioclimatic design, both as regards the choice of the site, the orientation and arrangement of the blocks, both as regards the construction characteristics and materials. Thus, we need to understand and evaluate how to reduce consumption and transform existing buildings into nearly Zero Energy Buildings. More specifically, we are attempting at answering if, adopting (some of) the previously proposed passive solutions, energy consumptions are small enough that they can be covered through the sole use of renewable energy. Therefore, we assumed to consider the combination of passive retrofitting interventions described in the previous section that is realization of a thermal insulation on vertical surfaces, together with the insulation of the roof and replacement of windows. The combination of these passive solutions allows a substantial reduction of the energy requirements. To evaluate the feasibility of nZEBs in the selected buildings, the installation of a photovoltaic system has been assumed, considering it as the renewable source for the production of electrical energy to supply the cooling system with AC units, the heating system with heat pump and the electricity for other domestic uses. The use of a PV plant on the roof coverings is able to set to zero the energy balance of retrofitted buildings.

4. Conclusion

The nearly Zero Energy in existing building of the Mediterranean cities is thus proved to be a technically feasible goal, but it is necessary to face the problem of very high costs due to the need to operate both active and passive interventions, which are amortized over a relatively long time, generally comparable with the life of the systems of energy production from renewable sources. It is possible to achieve counterbalance of economic cost by the proposed additions which will be used to set to zero energy the Buildings. Nonetheless, the effective reduction of energy consumption towards zero energy buildings and districts is and remains an unavoidable objective, especially in the Mediterranean urban areas, where the dramatic



combination of HI phenomena, fuel poverty and global overheating is severely threatening both humans and environment.

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Economic Assessment of Refurbishment of Federal Public Housing in the UAE (Best Paper SB13 Dubai)

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Abstract: *This paper assesses the economic viability of implementing refurbishment solutions to existing public housing in the UAE. Computer modelling was used to estimate the potential reduction in cooling loads and resulting savings in electricity consumption in four villa models representing the public housing from 1980s -2010s. The results indicated that the most cost efficient solution is the application of wall insulation to models built in 2000s-2010s, upgrading glazing for models built in 1990s, and roof insulation for models built in 1980s or earlier. The most cost-effective refurbishment practices had a simple payback period of 10 years. A combined refurbishment scenario will achieve higher electricity savings up to 23%-36%, while the payback period will only increase by 1-2 years compared to the most cost-efficient solutions. There are many side benefits for the refurbishment process but no monetary value was assigned to them thus they were not included in the economic analysis.*

Keywords, Energy modelling, Economic assessment, Refurbishment strategies, UAE

Introduction

The building construction sector has been an active and fast growing business in the United Arab Emirates for the past two decades. The construction sector represented the second highest gross domestic product (GDP) growth in 2008 [1]. This continuous growth of the construction industry has led to raised concerns of its impact on the environment. The recognition of the sustainable development approach is relatively new in the UAE. It is a natural response to mitigate the environmental impacts of the building construction industry, especially since the UAE has the highest ecological footprint per person worldwide in 2007 [2]. The governmental agencies are playing a great role to mitigate the situation through building regulations that aim in reducing the environmental impact of the built environment. The UAE's commitment to reduce CO₂ emissions in the near future is reflected in the sustainability frameworks in 2020 and 2030.

Sustainability rating systems have been established around the World to reduce the environmental impact of the buildings. Such rating systems like LEED, BREEAM, and Green Star are used as tools to assess the sustainability aspects of the building during the design and construction stages. However, recently emphasis has been to minimize environmental impact of existing buildings during operation stages i.e. LEED EB+OM.

However, in the UAE, green building regulations were introduced recently. The Emirate of Abu Dhabi introduced the Estidama Pearl Rating System; which is a green building rating; and enforced mandatory requirements on all new buildings since 2010. Dubai Municipality

has enforced the Green Building Regulations in 2014. However, such regulations target new buildings only, whereas the larger stock is represented in the existing buildings.

This paper presents an economic feasibility study conducted on several refurbishment scenarios to upgrade existing federal housing typologies. Four common typologies representing different decades were assessed in terms of energy consumption through computer energy modeling. For each model, multiple refurbishment techniques were applied using thermal insulation and highly efficient glazing. The paper will assess the economic feasibility of the refurbishment applications and their impact on energy savings.

Literature Review

After the discovery of oil in 1960s, the UAE have witnessed a dramatic development in all sectors including construction. The environmental impact of the construction was reflected in the increase in energy consumption. Since 1980, the UAE continued to have the highest energy consumption per capita compared to an average rate in the Middle East, Europe, USA, and the World [3]. However, the peak rate was witnessed between 1985 and 1995.

The built environment is estimated to contribute to nearly two-fifth of the total energy consumption in the country in which only 0.5-2% are considered as new developments which adhere to the newly set green building regulations [4]. Therefore the major energy savings can be achieved by refurbishing the existing buildings. Many researches were conducted in different climates to assess the potential of energy savings that could be achieved through building retrofitting. Some of which focused on active systems such as upgrades of the HVAC system [5], others highlighted low-cost solutions based on passive strategies such as adding insulation [6]. Researchers highlighted the importance of addressing cost-efficient refurbishment solutions by providing a multi-objective approach. A research conducted on a residential building in Portugal proposed multiple refurbishment scenarios including upgrades for the wall, roof and glazing. The study indicated that a one level upgrade in refurbishment solutions although of 2.5% increased cost results in 32% additional annual energy savings [7].

A recent study conducted in the UAE addressing Federal housing projects built by the Ministry of Public Works since 1974, highlighted the potential of energy savings up to 30.8% through insulation and glazing upgrading [4]. Further to the conducted study, this research selected four typologies representing decades from 1980s to 2010s; as summarized in Table 1. *Table 1 Summary data for four housing models (Source: Alawadi et al. 2013)*

Model Number	Decade built	Villa Configuration	Total floor area (m2)	Window/wall ratio (%)
B74	1980s	G	114	3.7
670	1990s	G	351	6.7
717	2000s	G+1	394	11.5
762	2010s	G+1	472	11.1

The proposed upgrades aims to achieve the thermal properties set by Estidama. Table 2 provides a summary of the minimum requirements in compliance with 1 Pearl Villa Rating, and the requirements to achieve the optional credit 2-5 Pearls [8].

Table 2 Summary of thermal performance requirements in compliance with 1 pearl & 2 pearls rating.

Element	1 Pearl	2 Pearls

Infiltration (ACH)	0.350	0.200
Wall U-value (W/m ² .K)	0.320	0.290
Floor U-value (W/m ² .K)	0.150	0.140
Roof U-value (W/m ² .K)	0.140	0.120
Glazing U-value (W/m ² .K)	2.200	1.900
Glazing (SHGC)	0.4	0.3

Implementation of passive retrofitting techniques to upgrade external building envelope could be achieved by adding thermal insulation. Insulation boards and curtain wall are two possible scenarios in this context. Estidama Villa Product Database (EVPD) recommended several insulation products [9]. The first method considers a thermal insulation product that could be used as a curtain wall application to provide additional external insulation mechanically fixed to the existing structure and then covered by external cladding finishing. Another method is for the insulation boards to be fixed internally. Both methods consider rigid board insulation.

Methodology

Energy modeling and building simulation has become a widely popular and reliable tool used by researcher and designers in the past few decades. Building simulation softwares are capable of conducting CFD analysis, thermal modeling, energy simulation, daylight analysis, and many other parameters. Softwares such as Energy Plus [6&10], DOE-2 [11,12 &13], eQUEST [14], EOTECT [15&16], IES VE [17&18] have been utilized for researches to assess energy consumption and thermal comfort. For this study, IES VE has been used as an energy modeling tool to assess energy savings and reductions in cooling loads for four common housing typologies. In a comparison with 20 commonly used energy simulation software, IES VE provided various interlinked parameters and assessment options including building envelope, daylight and solar variables which are important for this study [19]. An existing villa, constructed in Sharjah in 1995 and refurbished in 2005, has been used to validate the software (Refer to Figure 1). The results indicated a difference of only 1.3% from actual utility bills; excluding the summer months when the tenants go on vacation (Refer to Figure 2). IES has proven high reliability and accuracy of its results.



Figure 1 Picture of the villa used for validation.

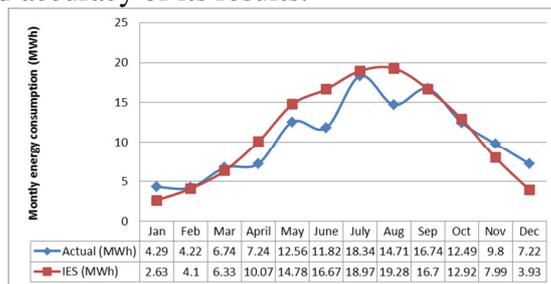


Figure 2 Actual and IES_VE predicted energy consumption of the validation villa

Four housing models were simulated using IES VE representing each decade between 1980s-2010s. The models represent the most common models built by the MoPW in five Emirates [4]. The energy model of each typology was based on the design details provided by MoPW. The data included architectural layouts and details, construction materials details, finishing schedules, and structural details. The IES simulation tools were used to calculate cooling loads and electricity consumption monthly and annually for each model. The simulation was



conducted on the basic model representing as-built construction conditions, then simulations were carried for elemental refurbishment solutions for external walls, roof and glazing separately while other parameters were fixed as the baseline model. Upgrades of each element considered two potential scenarios to achieve 1 pearl and 2 pearls requirements, respectively. Moreover, two simulations were conducted to represent the combined upgrade of all three applications one for the 1 pearl requirements and another for the 2 pearls requirements.

The virtual retrofitting configurations were used to assess annual savings in electricity consumption and cooling loads which will be presented in the following section. Also, the results were used to conduct a cost study using mathematical analysis to assess the economic feasibility of each refurbishment scenario using Simple-Payback-Period analysis (SPP).

Results and Discussion

Computer modeling and energy simulation was used to assess the passive refurbishment techniques addressed in the study inclusive of addition of thermal insulation to the external walls, roof, and upgrading the glazing. The IES simulation was used to calculate the annual savings in cooling loads and electricity consumption and respective cost savings due to reduction in annual electricity consumption of the refurbishment scenarios (refer to Table 3).

The estimated cost of the different refurbishment scenarios was calculated based on an estimated refurbishment unit cost inclusive of the material, transportation, and installation costs in the UAE (refer to Table 4). The estimated SPP was calculated by dividing the refurbishment cost by the cost of the energy saved annually. According to the calculations for simple payback period presented in Table 5, it was noted that the minimum estimated SPP was around 8 years, with the SPP for the majority of the strategies was more than 10 years. It is important to highlight that the payback period calculations exclude the government electricity cost subsidies, building envelope climatic performance upgrades such as humidity resistance, air tightness, aesthetical appearance, and future increases in the cost of electricity. It is expected that once all the benefits are quantified, the SPP analysis will result in reasonable timeframe for the owners to recoup their initial investment cost.

Table 3 Summary of annual savings in cooling loads and electricity and corresponding cost savings.

Villa model No.	Refurbished element (area m ²)	1 Pearl Configuration			2 Pearls Configuration		
		Cooling load saving (MWh/yr)	Electricity* saving (MW _e h/yr)	Cost saving** (AED/yr)	Cooling load saving (MWh/yr)	Electricity* saving (MW _e h/yr)	Cost saving** (AED/yr)
B74	Wall (172.87)	13.994	5.598	1847.23	14.161	5.664	1869.21
	Roof (67.8)	6.914	2.766	912.70	6.961	2.784	918.80
	Glazing (3.38)	0.784	0.313	103.42	0.905	0.362	119.45
	All	23.615	9.446	3117.13	24.054	9.622	3175.15
670	Wall (454.60)	49.117	19.647	6483.43	49.714	19.886	6562.26
	Roof (352.63)	29.474	11.790	3890.57	29.764	11.906	3928.84
	Glazing (30.37)	6.827	2.731	901.15	8.102	3.241	1069.46
	All	91.697	36.679	12104.04	94.324	37.730	12450.79
717	Wall (443.99)	47.276	18.911	6240.45	47.844	19.138	6315.40
	Roof (208.10)	15.700	6.280	2072.41	15.854	6.342	2092.70
	Glazing (51.05)	5.108	2.043	674.30	6.880	2.752	908.15
	All	72.139	28.856	9522.37	75.225	30.090	9929.74
762	Wall (343.14)	37.808	15.123	4990.71	38.274	15.309	5052.13

Villa model No.	Refurbished element (area m ²)	1 Pearl Configuration			2 Pearls Configuration		
		Cooling load saving (MWh/yr)	Electricity [*] saving (MWh/yr)	Cost saving ^{**} (AED/yr)	Cooling load saving (MWh/yr)	Electricity [*] saving (MWh/yr)	Cost saving ^{**} (AED/yr)
	Roof (160.2)	13.776	5.510	1818.41	13.908	5.563	1835.82
	Glazing (38.1)	-0.660 ^{***}	-0.264 ^{***}	-87.11 ^{***}	0.826	0.330	109.02
	All	53.429	21.372	7052.68	55.253	22.101	7293.38

* Assuming a HVAC system with a coefficient of performance (COP) of 2.5

** Using electricity rate of 0.33 AED/kWh

*** Existing glazing better than 1 Pearl requirements.

Table 4 Refurbishment unit cost in the UAE

Refurbished construction element	Unit refurbishment cost (AED/ m ²); inclusive of supply, installation and painting (not for glazing)	
	1 Pearl requirements	2 Pearls requirements
Wall (insulation boards)	140	165
Wall (curtain wall)	300	325
Roof	125	150
Glazing	260	280

The results presented in Figure 3 highlights the percentage of savings in electrical consumption for each villa model. The highest savings could be achieved by implementing an optimized refurbishment of all elements at once i.e. upgrade of walls, roof and glazing. However, upgrading thermal insulation for the roof in the earlier models is more efficient relative to the other individual retrofitting. This is due to the roof area representing over 30% of the total surface area of the building envelope since these models are single story houses.

In the newer models (717 & 762) the external wall refurbishment to 1 Pearl thermal insulation properties is deemed the optimal solution in terms of energy savings and economic feasibility. These are two story houses and thus the wall surface area becomes more important than the roof surface area of the older single-story models. It is expected to achieve up to 17.5% reductions in electrical consumption for the minimal expected payback period (9-10 years).

Table 5 Summary Data of refurbishment cost, annual cost savings and simple payback period

Villa model No.	Refurbished construction element	1 Pearl Configuration			2 Pearls Configuration		
		Refurbishment cost (AED)	Cost saving (AED/yr)	Simple payback period (yr)	Refurbishment cost (AED)	Cost saving (AED/yr)	Simple payback period (yr)
B74	Wall (insulation boards)	24201.80	1847.23	13.10	28523.55	1869.21	15.26
	Wall (curtain wall)	51861.00	1847.23	28.07	56182.75	1869.21	30.06
	Roof	8475.00	912.70	9.29	10170.00	918.80	11.07
	Glazing	1658.80	103.42	16.04	1786.40	119.45	14.96
	All (insulation boards)	34335.60	3117.13	11.02	40479.95	3175.15	12.75
	All (curtain wall)	61994.80	3117.13	19.89	68139.15	3175.15	21.46
670	Wall (insulation boards)	63644.00	6483.43	9.82	75009.00	6562.26	11.43
	Wall (curtain wall)	136380.00	6483.43	21.04	147745.00	6562.26	22.51
	Roof	44078.75	3890.57	11.33	52894.50	3928.84	13.46
	Glazing	7896.20	901.15	8.76	8503.60	1069.46	7.95
	All (insulation boards)	115618.95	12104.04	9.55	136407.10	12450.79	10.96
	All (curtain wall)	188354.95	12104.04	15.56	209143.10	12450.79	16.80
717	Wall (insulation boards)	62158.60	6240.45	9.96	73258.35	6315.40	11.43
	Wall (curtain wall)	133197.00	6240.45	21.34	144296.75	6315.40	22.85
	Roof	26012.50	2072.41	12.55	31215.00	2092.70	14.92
	Glazing	13273.00	674.30	19.68	14294.00	908.15	15.74
	All (insulation)	101444.10	9522.37	10.65	118767.35	9929.74	11.96

Villa model No.	Refurbished construction element	1 Pearl Configuration			2 Pearls Configuration		
		Refurbishment cost (AED)	Cost saving (AED/yr)	Simple payback period (yr)	Refurbishment cost (AED)	Cost saving (AED/yr)	Simple payback period (yr)
762	boards)						
	All (curtain wall)	172482.50	9522.37	18.11	189805.75	9929.74	19.11
	Wall (insulation boards)	48039.60	4990.71	9.63	56618.10	5052.13	11.21
	Wall (curtain wall)	102942.00	4990.71	20.63	111520.50	5052.13	22.07
	Roof	20025.00	1818.41	11.01	24030.00	1835.82	13.09
	Glazing	NA	NA	NA	10668.00	109.02	97.85
	All (insulation boards)	77970.60	7052.68	11.06	91316.10	7293.38	12.52
All (curtain wall)	132873.00	7052.68	18.84	146218.50	7293.38	20.05	

The results indicate that the most cost-effective solution is 1 Pearl wall insulation for models 717 & 762, 1 pearl roof for model 670, and 1 pearl glazing for model B74. However, for all models, the second or third level refurbishment solution although less cost-efficient, it can achieve between 23-36% savings in electrical consumption. Therefore, it is recommended to upgrade the models to 1 Pearl combined scenario instead of individual elemental upgrades since the SPP will only increase by (1-2) years.

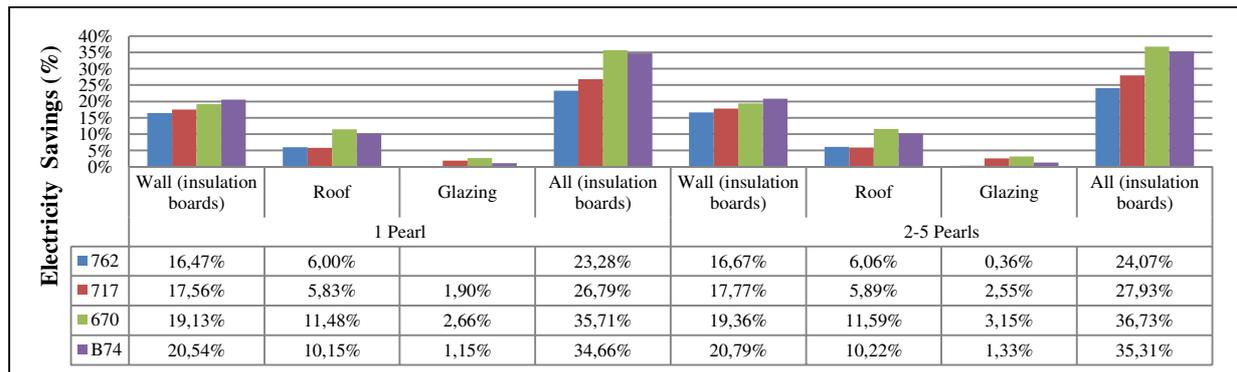


Figure 3 Reduction in electricity consumption due to refurbishment applications

Conclusion

Computer modeling was used to assess the savings in electricity consumption for four public housing models in the UAE, representing four decades from 1980s to 2010s. Nine building simulations for each of the four models were conducted to assess savings due to individual elemental refurbishment and combined scenarios considering upgrades to 1 and 2 pearl rating thermal properties. The potential savings range from 23% for the latest models up to 36% for the earlier ones. The feasibility study indicated that the most feasible refurbishment solution for model B74 -1980s- is for 1 pearl roof insulation, for model 670 -1990s- is 1 pearl glazing, for model 717 -2000s- is 1 pearl wall insulation, and for model 762 -2010s- is 1 pearl wall insulation. Although those solutions require the minimum payback period (8-10 years), the solutions are not the most efficient for energy savings. Therefore a combined solution considering wall, roof and glazing upgrades to 1 pearl performance all together can reduce the electricity consumption by 23%-36%.

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Session 86:

What role should public housing play in sustainable building?

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Sustainability Metrics - A Public Housing Empirical Experience

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Abstract: *The Hong Kong Housing Authority (HKHA) manages a housing stock of 740,000 public rental housing (PRH) units of different block type designs and ages. In driving sustainability of the existing PRH, HKHA adopts a set of sustainability-focused maintenance strategy. Sustainability performance of different housing block types is gauged by using the Hong Kong Quality Assurance Agency Sustainable Building Index (SBI), which is a green building rating system, to facilitate the identification of areas for improvement and setting of priorities in the formulation of long-term maintenance and improvement (M&I) programmes. To maximize cost effectiveness, HKHA applies SBI metrics strategically to a selective number of PRH estates which represent the majority of the block type designs to obtain an overview of sustainability performance of the existing housing stock and makes use of the Building Environmental Assessment Method (BEAM) Plus for planning of specific estate-based improvement project.*

Sustainability Metrics, Sustainable Building Index, greenhouse gas emission, BEAM Plus

1. Introduction

In Hong Kong, over two million people (about 30% of the population) live in public rental housing (PRH) estates. The Hong Kong Housing Authority (HKHA) is a statutory body that develops and implements the public housing programme for low income families. Currently, the HKHA is managing some 740,000 PRH units in about 1,200 multi-storey buildings of different block type designs, ages and building conditions located in more than 200 estates. To sustain the PRH stock while coping with the changing needs of the community over time, the HKHA establishes its sustainability-focused maintenance strategy in the economic, social and environmental dimensions which sets the blue print for the implementation of maintenance and improvement (M&I) programmes (Figure 1).



Figure 1 : Three Dimensions of Sustainability-focused Maintenance Strategy



To effectively formulate the long-term maintenance and improvement (M&I) programmes for the PRH stock in such scale, it is prudent to gauge the sustainability performance of the portfolio, which mainly consists of over 20 standard block type designs developed over the decades, by a building sustainability performance verification system so that the necessary improvement schemes can be formulated to upkeep and raise their sustainability. This paper describes how the HKHA drives building sustainability through a sustainability-focused maintenance strategy with an aid of a set of sustainability metrics verification system.

2. Sustainability Metrics

Over the past decade, different green building assessment systems or certification schemes were published with the aim of enhancing buildings' sustainability performance. Globally, there are various green building rating systems or certification schemes. For example, the Building Research Establishment Environmental Assessment Method (BREEAM) from the United Kingdom, the Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) from Japan and the Leadership in Energy and Environmental Design (LEED) from the United States of America. In Hong Kong, there is a growing use of the Building Environmental Assessment Method (BEAM) Plus for new building projects since it forms one of the pre-requisites for granting gross floor area concessions from the Building Authority. In late 2012, the Hong Kong Quality Assurance Agency (HKQAA) launched a building assessment scheme named HKQAA Sustainable Building Index (SBI), which is a territory-wide benchmarking tool for the environmental, social and economic performance measurement for existing buildings.

2.1 Sustainability Challenges in Hong Kong

Hong Kong is one of the most densely populated cities in the world. Being a service focused economy without major energy-intensive industries, electricity generation is the major source of greenhouse gas (GHG) emissions in Hong Kong, which accounts for over 60% of the total local emissions. Among various end uses of electricity, buildings are the most consumptive, which accounts for some 89% in Hong Kong [1].

Hong Kong is facing building aging problems and the HKHA is of no exception. At present, about 30% of the PRH is aged 30 years or above. While the government has implemented the Mandatory Building Inspection Scheme (MBIS) and Mandatory Window Inspection Scheme (MWIS) to address public concern on the safety and quality of aged buildings, the HKHA has also proactively formulated a series of improvement schemes to address the needs of the aging population of its tenants as well as the new generation in the following decade.

2.2 Sustainability Research and the HKQAA SBI

To promulgate sustainable building to building owners and property management companies, the HKQAA has developed a quantitative Sustainable Building Index (SBI) for assessment of the existing buildings in the environmental, social and economic aspects, which is tailored to the unique circumstances of Hong Kong [2]. Local contexts are included by taking into account the Hong Kong legislations, carbon reduction in buildings and rateable value in economic term. The HKQAA's sustainability metrics was developed based on the United

Nations Environment Programme – Sustainable Buildings and Construction Initiative’s (UNEP-FI/ SBCI’s) Financial and Sustainability Metrics Report 2009 [3] and a few key ISO standards on building sustainability with the salient view to identifying significant Performance Indicators (PIs) to stakeholders; allowing opportunities for improvement; standardizing PIs for benchmarking with established norm performance; and addressing key sustainability issues in Hong Kong. The assessment system is practical and inexpensive.

The metrics encompass 20 PIs addressing key local sustainability issues and facilitating the stakeholders, the building owners and the property managers to benchmark their building performance in the social, economic and environmental aspects (Table 1).

Aspects	Issues	Performance Indicators	Measuring Approach
Environmental	Climate Change	Greenhouse gas (GHG) Emissions	GHG per unit internal occupied floor area (IOFA)
	Ozone Destruction	Release of ozone-depleting substances into the atmosphere	Ozone-depleting substances emissions per unit IOFA
	Biodiversity	Ecology in building	Adoption of recommended practices
	Use of Resources	Use of fresh water	Water consumption per unit IOFA
		Use biodegradable/organic materials	Adoption of recommended practices
	Waste recycling	Waste recycled per unit IOFA	
Social	Building Security and Safety	Building strength and quality	Level of regulatory compliance and beyond
		Fire prevention	Level of regulatory compliance and beyond
		Safety of lifts and escalators	Level of regulatory compliance and beyond
		Emergency planning	Adoption of recommended practices
		Designing out crime	Crime rate
	Health and Comfort of Users	User comfort - Lighting comfort	Building user satisfaction survey
		User comfort - Thermal comfort	Building user satisfaction survey
		User comfort - Noise control	Building user satisfaction survey
		Indoor air quality	Building user satisfaction survey
		Quality of fresh water	Adoption of recommended practices
Social Infrastructure	Accessibility to transportation, public facilities and barrier free facilities	Building user satisfaction survey	
Harmonized Neighbourhood	Neighbours' satisfaction	Neighbours satisfaction survey	
Economic	Asset Value	Rateable value of building	Percentage change in rateable value
	Building Maintenance	Expenses on maintaining building's operational continuity	Maintenance expenses per unit IOFA

Table 1 : Overview of the HKQAA SBI Metrics

3. A Public Housing Empirical Experience

3.1 Pilot Study

To effectively formulate the long-term maintenance and improvement (M&I) programmes for the PRH stock of such magnitude, it is prudent to gauge the sustainability performance of the respective block types of the portfolio so that the necessary improvement schemes can be implemented to upkeep and raise their sustainability. After studying the application of SBI and its potential benefits, the HKHA enrolled a selective number of estates which represent the majority of the standard block type designs of PRH as pilot scheme of SBI in 2012. The scope of the pilot scheme not only covers the enrolment, upkeep and improvement of the building sustainability of the selected PRH blocks, it also requires training for management and frontline staff; compilation of template automation to facilitate data input and analysis, collection of building information for the 20 performance indicators; report on performance;



verification of the report and review for continual improvement. In the following paragraphs, the HKHA shares its experience in overcoming the technical rigours and highlights the means for improving the sustainability performance of the PRH estates.

3.1.1. Environmental Aspects

From the pilot study, the HKHA has identified that the key issues affecting the sustainability performance of the PRH in regard to the environmental aspect are the GHG emissions and waste recycling.

Reduction of GHG Emissions

In fact, the HKHA has started establishing the baseline for GHG Emissions for the major housing block types since 2008 and developed a systematic methodology for collection of data for measuring GHG emissions of all major block type designs. The results indicated that electric lighting and lift system are the two major items attributable to GHG emissions of the communal facilities in PRH estates.

Targeting at reducing energy consumption for electric lighting, a series of energy saving measures are put in place, including the optimized use of daylight through employment of photo sensors and time switches, use of T-5 fluorescent tubes and in 2012, a 42-month programme of replacing electromagnetic ballast with energy-saving electronic ballast for the light fittings in all existing estates was launched.

As more data were gathered and analysed under the SBI pilot study, opportunity for refinement of the energy saving programmes was revealed after the first verification exercise of SBI for the enrolled estates. It was noted from the PIs that some estates having a higher intensity of GHG emissions of the common areas per unit of useable floor area of the housing block should be given a higher priority in programming for the energy saving initiatives. As such, the replacement programme for electronic ballasts was refined by re-shuffling some of the estates according to the results of the PIs of the SBI.

With respect to the lift services, the HKHA has implemented the Lift Modernization Programme since 1989. The programme includes replacement of the aged lift cars, machinery and control system with a view to improve efficiency, riding comfort and to enhance accessibility to every floor of the housing block in older estates with additional lift landings. All the new lift systems are now equipped with enhanced comfort ride, greater passenger capacity, higher speed, more landings and landing announcement system, etc. On the energy saving front, these new lifts are more energy efficient by trimming down energy consumption of over 30% when compared with the old ones.

Waste Recycling

To facilitate effective waste recycling, allocation of sufficient space for recycling operations at designated points is found useful. To boost tenants' participation in waste recycling, tenants are encouraged to deliver their recyclable household waste to the collection counters

in all PRH estates for exchange of small incentives. The HKHA has been actively implementing the Source Separation of Domestic Waste Programme. 31,660 tonnes of used paper, plastic bottles, aluminium cans and used clothes were collected in 2012/13.

To minimize food waste, a pilot scheme on food waste recycling using on-site composters was launched in December 2011. The scheme now expands to 14 estates using off-site food waste recycling for conversion into fish feed as well as on-site recycling for compost by micro-organisms. Over 3,000 households have registered to the scheme and the average weight of food waste collected per month is about 24,590kg. To further engage tenants in food waste reduction, a series of estate-wide campaigns are held, such as the food waste green recipe competition and broadcast of educational videos on the Housing Channel.

Other Findings

The SBI has also provided a useful means for comparison of the communal fresh water consumption per unit of internal occupied floor area of the standard block types. Some examples are demonstrated in Table 2.

Block Type	Fresh water consumption (m ³ per 1,000m ² per year)
A	130
B	63
C	46

Table 2: Fresh water consumption of three block type designs

It is observed that water consumption of Block Type A is on a higher side than the other standard block types. After further investigation, it is found that the higher water consumption is attributable to a higher greening of 40% site coverage. As such, water saving measures, including the review of planting and irrigation modes, the choice of plant and the use of rainwater harvesting system, would be further studied.

3.1.2 Social Aspects

Findings of the pilot study reinforce the effectiveness of the people-oriented and sustainability-focused maintenance strategy adopted by the HKHA as it well meets the PIs under the social aspects of the SBI.

In regard to building security and safety, apart from the routine inspections of the common parts of the building, the HKHA takes a higher standard through implementation of the Total Maintenance Scheme (TMS), which is a proactive and customer-oriented maintenance programme to upkeep the conditions of the building elements and installations. Well-trained In-flat Inspection Ambassadors are appointed to conduct flat-to-flat survey to PRH blocks aged over 10 years at a 5-year cycle to ensure prompt repair and education for tenants about flat maintenance to prevent minor repair issues from blowing up into major problems. The second 5-year cycle was launched in 2011 with the in-flat inspection programme successfully rolled out in 97 estates. Among these estates, 62 estates were completed in March 2014. Since the launch of TMS, the tenants' satisfaction rates have been maintained around 80%.



Emergency planning is always an important item on the job list in the HKHA. Besides the set of emergency procedures laid down in the manual and the regular drills, the HKHA has adopted a systematic approach of ISO 31000 risk management framework for maintenance and improvement works since 2012. External and internal contexts are reviewed in detail at the process of hazard identification and risk assessment. Such framework facilitates the assessment of complex risks.

To sustain the aged estates while meeting the up-to-date needs of the tenants is a challenge to the HKHA. Upgrading of the social infrastructure and communal facilities, provision of barrier free access and enhancement for pedestrian circulation are some of the major considerations in the planning of the estate improvement project under the HKHA's Estate Improvement Programme (EIP). The EIP is tailored for the aged estates, which have been appraised under the Comprehensive Structural Investigation Programme confirming the estate is structurally safe and economically viable to maintain. The key concerns of the tenants in a particular estate are collected through surveys and consultation. The improvement works are people-oriented, which cater for the needs of different age groups, particularly the elderly, rather than facility-based. Lifts towers are built attaching to the housing blocks lacking lift facilities, as well as to estates where there are large level differences between building platforms. The communal facilities and the uses of non-domestic premises are brought up-to-date to suit the latest needs of the tenants as well as the neighbourhood. For example, the innovative conversion of a car parking block with long standing vacancy rate to an education centre. Recreational facilities are enhanced to cater for different age groups and re-shaping public space for better social interaction, including installation of fitness equipment for the elderly and play equipment for the children. Weather-protected passage and barrier-free access are integrated into a master pedestrian network to improve pedestrian circulation bearing the needs of the elderly and disabled tenants in mind.

3.1.3 Economic Aspects

Building maintenance expenses per unit of the internal occupied floor area is a key issue in measuring the economic performance of the building under the SBI. To maximise cost effectiveness, the HKHA has developed a set of M&I cost indicators for budget control and monitoring of M&I expenses. With the customer-oriented preventive maintenance being implemented under the TMS, the rate of breakdown repairs at PRH units are well contained, which reduces the expenses on the more costly responsive maintenance.

With the implementation of various energy saving initiatives, the electricity consumption in estate public area has been progressively reduced. In 2012/13, the electricity consumption in public areas of PRH blocks was 59.3 kWh per flat per month [4]. Such consumption figure represented a reduction of 14.6% in five years (Figure 2). To raise energy consumption efficiency and to support carbon reduction in Hong Kong, the HKHA implemented ISO 50001 for all PRH estates in two phases. Phase One commenced in October 2013 and full certification for all existing estates is scheduled in April 2015.

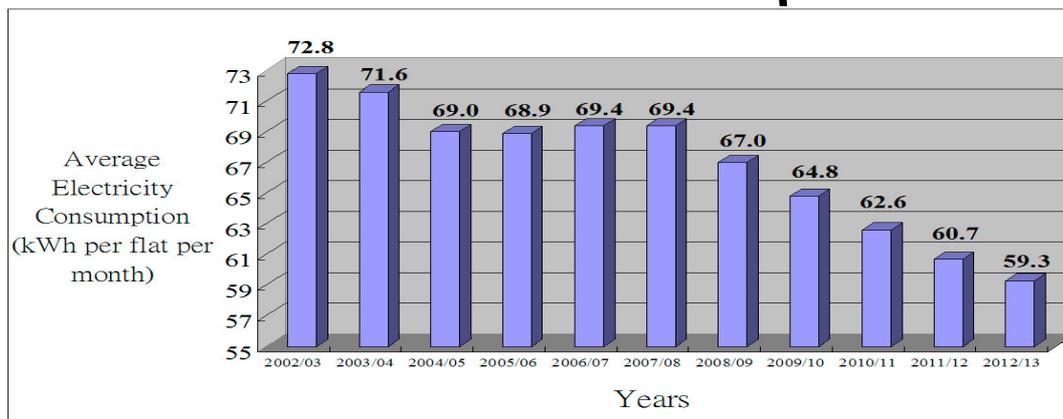


Figure 2: Average Electricity Consumption in Public Area of Estates [4]

3.2 Review of Pilot Study

Other intangible benefits are gained through the enrolment exercise. For example, the awareness of frontline staff about building sustainability has increased. They are motivated by the scheme and more actively participate in the implementation of environmental, social and economic initiatives. The SBI provides a comprehensive and yet very practical benchmarking mechanism for building sustainability. The quantified performance indicators allow participants to examine the building performance in the respective aspects and facilitate self-comparison over time.

According to the enrolment result, the sustainability performance of all the PRH blocks of the pilot scheme are found above the norm and are granted with the HKQAA SBI Verified Mark. In fact, the HKHA is the first organization obtains the HKQAA SBI Verified Mark. As at the first quarter of 2014, there are 40 PRH blocks enrolled to the SBI.

While the SBI encompasses the building performance in the environmental, social and economic aspects with enhanced usability, the system enables an effective broad-brush scanning of the sustainability performance for a large housing portfolio of various block type designs and reveals the areas for improvement with quantifiable reference through PIs.

Enhanced Management System for Sustainable Building

From the experience gained in the pilot scheme for SBI, the HKHA has established a structured verification system under its Environmental Management System and strategically selected a number of PRH estates which represent the majority of the block type designs for enrolment to the SBI Scheme. The objective is to facilitate the planning of the long-term maintenance and improvement strategy for enhancing the sustainability performance of the housing stock.

Application of Other Green Building Rating System

On the other hand, for the design planning of a specific estate-based improvement project, the adoption of BEAM Plus may be useful. The BEAM Plus methodology is designed with an environmental orientation and engineering approach, which provides detailed environmental rating to facilitate improvement through design, specification and testing [5].



The HKHA has applied BEAM Plus methodology in the estate improvement project at Kwai Shing West Estate, which is 39 years old and consists of over 5,200 PRH flats in 10 housing blocks. Comprehensive assessments of site aspects, material aspects, water use, indoor environmental quality, innovations and addition under planning, design, construction, operation and management provisions are conducted. Following completion of the feasibility study, Kwai Shing West Estate was registered with the Hong Kong Green Building Council for BEAM Plus certification and achieved 'Platinum' grading in the Provisional Assessment of BEAM Plus in May 2014. It is the first residential estate to be awarded "Platinum" for BEAM Plus Provisional Assessment in the category of existing buildings in Hong Kong. The experience gained in this project would be applied to similar improvement projects of the same block type design.

4. Conclusion

In driving sustainability of the existing PRH, the HKHA has adopted a sustainability-focused maintenance strategy incorporating social, environmental and economic initiatives with an effective building performance verification system of SBI. The quantifiable performance indicators provide essential information allowing the HKHA to examine the performance of different housing block types against the norm so that long-term M&I plans for the portfolio can be drawn up holistically with prioritization of various M&I programmes for different block types to rationalize the use of resources.

For specific estate-based improvement project, the HKHA makes use of the BEAM Plus for Existing Buildings, which involves sophisticated design tools, extensive data gathering, recording and detailed technical studies on environmental aspects. The experience gained together with the BEAM Plus ready specification developed for the individual estate improvement project will provide useful reference for similar improvement projects.

With the quality, environmental and energy management system (certified to ISO 9001, 14001 and 50001) in place, complemented with the building sustainability assessment tools, the sustainability performance of the PRH portfolio as well as the maintenance and management practices are closely monitored and reviewed for continual improvement. Through the implementation of the sustainability-focused maintenance strategy and long-term M&I programmes, the HKHA effectively upkeep and raises the sustainability of the existing PRH estates to achieve the goal of providing a sustainable living environment for the community.

Reference:

- [1] Guidelines to Account for and Report on Greenhouse Gas Emissions and Removals for Buildings (Commercial, Residential or Institutional Purposes) in Hong Kong, 2010 Edition, Environmental Protection Department and Electrical and Mechanical Services Department.
- [2] HKQAA Sustainable Building Index (SBI) Metrics Handbook and Report Template, Version 1.3 October 2013, the HKQAA.
- [3] Clare Lowe / Alfonso Ponce, United Nations Environment Programme – Sustainable Buildings and Construction Initiative's (UNEP-FI/ SBCI's) Financial and Sustainability Metrics Report 2009
- [4] 2012/13 Sustainability Report, Quest for Excellence in Low Carbon Housing, HKHA.
- [5] BEAM Plus Existing Buildings, Version 1.1 April 2010, BEAM Society.



“L’HDC” the CO2 indicator of L’Hospitalet in a P2P environmental governance towards NZEmissions Cities. A benchmark for S.E.A.P of signatories Covenant of Mayors.

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Abstract:

The environmental report " L' HDC" values environmental benefits of the project, works and lifespan of the building , public space and infrastructure. It is related to the carbon footprint of the project and works questionnaire. It covers the entire lifespan of the building , refurbishment , development and infrastructure. - The " L' HDC" is delivered to the application for the building permit to fill it with the final design and updating in asbuilt . It is an invitation to the private sector to work with government environmental objectives - . Administration marks the path and activates a Built Park Observatory focussing on Footprint, emissions of CO2 to the atmosphere, with the ultimate goal of improving the quality of urban life.

- To quantify the contribution of environmental government targets Europe-wide 202020 means putting it in value.

- Based on the declared contributions, we may design environmental policies and assign administrative returns that encourage decarbonization of the City of l' Hospitalet , Barcelona .

- Environmental governance, P2P

- Benchmark for S.E.A.P. Covenant of Mayors signatories

Key words:

"L' HDC"

Positive Environmental Report, Environmental Governance P2P

Carbon Footprint Observatory towards nZEB & nZECities

Checklist - Spreadsheet Form

Contribution to 202020: invite to join, encourage to decarbonization

Benchmark for S.E.A.P. Covenant of Mayors signatories



Section Title: "L'HDC" the CO2 indicator of L'H in a P2P environmental governance

Because of the European Directives 2010/31/EU and 2006/123/EC towards nZEB L'Hospitalet City Council has published a municipal ordinance regulating the Urban Activity and Licensing Works in prescribing the wording of the "Report environmental - L'HDC "to the License Application Major Private and Public Work.

Collaborating in the writing and maintenance: the "ITeC", Institute of Building Technology of Catalonia. And the "OCCC" The Catalan Office for Climate Change, of the Gov. of Catalonia

Use Calculators CO2: the OCCC; ITeC, TCQ-GMA, BEDEC Data Base, and LEADER-CALENER form the Ministerio de Fomento, and relies on HADES, Tool Help from GBCEspaña, and also on Sustainable Construction Agenda CAATEB

It is a 2.0-Tool, a software application that runs different calculators of Environmental Impact that quantified emissions of CO2 into the atmosphere.

-Acts on Demand with the aim of influencing the Offer, the Productive Sector.

It means the recognition of environmental choices

-Allows Encourage the Positive Contributions, Environmental Policy & Governance Design and greening public competitions P2P

-“L'HDC”. Is a Benchmark for S.E.A.P. Covenant of Mayors signatories

Environmental positive report "the HDC " is a Observatory of Environmental, Economic and Social Proposal Sustainability in the municipality of l'Hospitalet, Barcelona.

A Checklist highlights environmental and social sustainability contemplating air quality and wellness users. A form, spreadsheet , quantify the carbon footprint, CO2 of the construction process and lifespan of the building, rehabilitation and infrastructure development. Observe the impact categories: energy / water / materials&waste with CO2 calculators accessible to websites from the OCCC, Catalan Office of Climate Change; IteC, Institute of Building Technology of Catalonia, and the Ministerio de Fomento calculator Lider-Calener .

The L'HDC report is Positive because it is compared with the reference building CTE, which is always improvable. We deliver to the architect an application for Major Constructions License in the project Basic phase and it must be filled by designing the Project specifications and updates at the asbuilt. The "L'HDC " invite to join Europe-wide Environmental targets of Public Administration head in order to minimise urban energy and environmental CO2 emissions in the atmosphere . And it does activate a new building and refurbishment park Observatory. To quantify the contribution of projects to European-wide goals " 2020 " and " nZEB & nZECities" means to achieve environmental policies and incentive plan to improve quality of urban live in l'Hospitalet, assigning administrative returns that encourage the decarbonization of l' Hospitalet , Barcelona.

“L’HDC” the CO2 indicator of L’Hospitalet in a P2P environmental governance towards NZEmissions Cities.

A benchmark for S.E.A.P of signatories Covenant of Mayors.

HOW IT WORKS

L’HDC

em d'energia i emissions de CO₂ en el cicle de vida d'un edifici

- Climate Zone
the Urban Policy
- Carbon Footprint
the Construction Process
the Life Cycle
and Maintainability
- Carbon Footprint
Public Space
and Infrastructure
the Life Cycle
and Maintainability
- Offsets
- Environmental Report
- Contributions to 2020, the comparison with the CTE



THE MENU: THE “L’HDC”, STEP BY STEP

THE L’HDC STEP BY STEP

1- FORM THE PROJECT'S CARBON FOOTPRINT AND ASBUILT

An Excel spreadsheet to calculate carbon footprint. The CO2 equivalent supplied in the atmosphere that is released by Urban Planning, Project Urbanization for Public Space, Urban Infrastructure and Building / Refurbishment / Regeneration. Observe the impact categories: Materials and Waste / Water and Energy / Mobility and Maintainability. Contemplate the Whole Cycle: The Groundworks on Site and / or Demolition / Deconstruction previous to Works. Covers the whole process areas: Extracting resources, Production and Transportation of the materials and the works in process to build, refurbishment & urban regeneration, including the Waste Management's own

3- "L'HDC" IS A POSITIVE REPORT

because it is based on Benchmarks of Ecoefficiency you may always improve. In "The HDC" is linked to the Declaration of Responsible planning permission for building. The report was issued in the Project and has to be updated to Asbuilt. Contemplates the Environmental Impact/Greening/Public Welfare."The HDC" promotes and highlights the positive agreement and contribution of the private sector to reach the European Public environmental objectives of the 2020: the reduction of CO2 equivalent emissions by improving energy efficiency and increased uptake in clean and renewable energy sources. This is the Primary Goal P.A.E.S. L'Hospitale: incorporating Energy Efficiency and Environmental

2- THE SUSTAINABILITY SURVEY

THE PROJECT/ASBUILT/LIFESPAN. Environmental, Economic and Social Sustainability. The

ENVIRONMENTAL REPORT ON L'HDC

"L'HDC" is a Footprint Indicator and CO2 Observatory of Sustainability of Projects/ Asbuilt/ Lifespan in

THE STEPS



THE “L’HDC”: THE CARBON FOOTPRINT INDICATOR

L'HDC

OVERVIEW OF THE BUILDING / PUBLIC SPACE / INFRASTRUCTURE											
PROPOSAL	=FITXA DE CO2'1H2R2		=FITXA DE CO2'1K3L3		CADASTRAL REFERENCE =FITXA DE CO2'1O3R3						
BUDGET	PEM	#REF!	INEXP.DM1	#REF!	=FITXA DE CO2'1M4	NEIGHBORHOOD	=FITXA DE CO2'1O4P4	DISTRICT	=FITXA DE CO2'1R4		
STREET	=FITXA DE CO2'1H4K4										
GEOGRAPHIC ORIENTATION	=FITXA DE CO2'1V2		BUILDING TYPE	=FITXA DE CO2'1K3Y3	PUBLIC E. TYPE	#REF!	URBAN QUALIFICATION	=FITXA DE CO2'1K2	P.G.M.	DATES WORKS	#REF!
AUTHOR	=FITXA DE CO2'1HSNS								BUILT AREA, m2	#REF!	

CARBON FOOTPRINT OF BUILDINGS / REFURBISHMENT / URBANIZATION / INFRASTRUCTURE AND URBAN PLANNING		EMBODIED ENERGY	CARBON FOOTPRINT	
1- CARBON FOOTPRINT OF THE NEW URBAN PLANNING, ASSOCIATED MOBILITY, URBAN RENEWAL AND REGENERATION	#REF!	kWh	#REF!	kg CO2
2- THE CARBON FOOTPRINT OF GROUNDWORKS AND/OR DECONSTRUCTION TO ADEQUATE SITE	#REF!	kWh	#REF!	kg CO2
3- THE CARBON FOOTPRINT OF MATERIALS AND WASTE CYCLES	#REF!	kWh	#REF!	kg CO2
4- THE CARBON FOOTPRINT OF THE WATER CYCLE	#REF!	kWh/year	#REF!	kg CO2/year
5- THE CARBON FOOTPRINT OF ENERGY AND MOBILITY CYCLES	#REF!	kWh/year	#REF!	kg CO2/year
6- THE COMPENSATIONS OF THE CARBON FOOTPRINT BY THE CONTRIBUTION BY THE LOCAL "URBAN GREEN"	#REF!		#REF!	kg CO2/year
7- THE FOOTPRINT SAVINGS REPORT, BY REDUCING DEMAND/ MOBILITY/ REFURBISHMENT/ REGENERATION/ ECODSIGN/ HOME AUTOMATION/ SMART	#REF!	kWh	#REF!	kg CO2/year

SURVEY ON ENVIRONMENTAL, ECONOMICAL, SOCIAL SUSTAINABILITY AND MAINTAINABILITY: FROM 1 TO 14										ECOEFFICIENCY PARAMETERS:		#REF!	RATING		
THE ENVIRONMENTAL SUSTAINABILITY				THE ECONOMICAL SUSTAINABILITY				THE SOCIAL SUSTAINABILITY			THE RELIABILITY				
#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!		
THE POSITIVE ENVIRONMENTAL REPORT				CONTRIBUTIONS TO THE L'HEAP 202020				#REF!	%	POSITIVE REPORT vs CTE		#REF!	kWh/year	#REF!	kg CO2/year

RESULTS: THE CARBON FOOTPRINT PROPOSAL/ WORKS/ LIFE SPAN/ AND CONTEMPLATING A USE CYCLE/ RENEWAL OF 10 YEARS												
PRODUCT CARBON FOOTPRINT / MATERIALS AND WASTE			WATER AND ENERGY CONSUMPTION CARBON FOOTPRINT / LIFE SPAN				FOOTPRINT REDUCTION		CO2 FOOTPRINT at 10 years			
THE CALCULATION	#REF!	kgCO2	#REF!	kgCO2/m2	#REF!	kgCO2/year	#REF!	kgCO2/10years	#REF!	COMPENSATED	#REF!	kgCO2
PROPOSAL vs ASBUILT	PROPOSAL FOOTPRINT	#REF!	kgCO2	ASBUILT FOOTPRINT	#REF!	kgCO2	DIFFERENTIAL FOOTPRINT		#REF!	kgCO2		



THE CO2 EXCEL WORKSHEET: NEW & REFURBISHMENT, PROJECT AND ASBUILT

INFO. DAT	PROJECT										GEO. FOCUS: N/E/W/S/E/NE/SW		PCM	URBAN CLASSIFICATION		
i	QUOTE	PERM	NEUP/DAM	CADASTRAL REFERENCE			BUILDING TYPE	TOWER/HOUSE/BETWEEN DIVIDING		GEO. FOCUS: N/E/W/S/E/NE/SW	PCM	URBAN CLASSIFICATION				
	STREET	OF	NEIGHBORHOOD	DISTRICT	DISTRICT	TYPE PUBLIC SPACE	PRIVATE / PUBLIC / PASSABLE									
	AUTHOR	BUILT AREA_m2	DATES WORK	PREVISION START WORKS	FINAL	FORECAST										
	THE CO2 WORKSHEET - 1 of 2 - THE PRODUCT'S FOOTPRINT AND IT'S LIFE SPAN, THE CYCLE OF MATERIALS&WASTE, WATER AND ENERGY															
MATERIALS & WASTE	LINK TO LITEC	RELEVANT MATERIALS * (1)	CO2f (t/ct)	m3	QUOTE %	REUSE m3	ECD DESIGN * (9)	EMISSIONS FROM CARRIAGE TO WORKS * (6)		kWh	FOOTPRINT * (7)					
	LINK TO DAP_C	MATERIAL_1		%	m3		km	kg CO2	kWh	kg CO2						
		MATERIAL_2		%	m3		km	kg CO2	kWh	kg CO2						
		MATERIAL_3		%	m3		km	kg CO2	kWh	kg CO2						
		MATERIAL_4		%	m3		km	kg CO2	kWh	kg CO2						
LINK TO OCT/COAC	SYSTEM_1		%	m3		km	kg CO2	kWh	kg CO2							
	SYSTEM_2		%	m3		km	kg CO2	kWh	kg CO2							
	SYSTEM_3		%	m3		km	kg CO2	kWh	kg CO2							
	TOTAL SAMPLING 1 - IN EVALUATED LEVEL ...%	0,00	0,00	%	0,00	m3	0,00	km	0,00	kg CO2	0,00	kWh	0,00	kg CO2		
	THE FOOTPRINT OF WASTE 105/2008 RD, 0.89 / 2010 * (3)	EXCAVATION	m3	RECYCLED	m3	MINIMIZED	m3	0,00	m3 TOTAL	kWh	0,00	kg CO2 eq				
LINK TO LOCCC	RESISTENCE/CONSTRUCTION REJECTED/BUILDING/INFRASTRUCTURE (1)	DEMOLITION	m3	WORK WASTE	m3	REUSED	m3	0,00	m3 TOTAL	kWh	0,00	kg CO2 eq				
	THE FOOTPRINT BY MEASURING THE PRODUCT: VIA "ITEC" TCC-GMA										kWh	kg CO2				
	TOTAL PRODUCTS' FOOTPRINT: APPLYING THE MOST EFFECTIVE VALUE BETWEEN (1 + 2 + 3) and 4)										kWh	kg CO2				
	LINK TO LOCCC	WATER CYCLE IN PUBLIC SPACE * (2)	FROM THE NETWORK / POTABLE			GROUNDWATER / PHREATIC * (1)			TOTAL WATER REQUIREMENTS			kWh/year * (7)	FOOTPRINT * (7)			
	LINK TO ENV. D.	WATER FOR IRRIGATION	m3/year	0,00	kWh/year	m3/year	kWh/year	TOTAL WATERING		0,00	m3/year	0,00	kWh/year	0,00	kg CO2/year	
WATER FOR MAINTENANCE AND CLEANING		m3/year	0,00	kWh/year	m3/year	kWh/year	TOTAL CLEANING		0,00	m3/year	0,00	kWh/year	0,00	kg CO2/year		
FOOTPRINT OF WATER DEMAND		m3/year	0,00	kWh/year	0,00	m3/year	0,00	TOTAL DEMAND		0,00	m3/year	0,00	kWh/year	0,00	kg CO2/year	
WATER USED IN 5-DAYS LIFE * (2)		DRINKING WATER NETWORK	m3/year	0,00	kWh/year	0,00	m3/year	0,00	NETWORK PHREATIC WATER * (1)		RETRIEVED/REUSED WATER	COLLECTED WATER / RAIN	TOTAL * (8)	FOOTPRINT * (8)		
LINK TO ENV. D.	CONSUMPTION / CAPTURE / FLOW / SOURCES	m3/year	0,00	kWh/year	m3/year	kWh/year	GREY WATER	m3/year	m3/year	0,00	kWh/year	0,00	kg CO2/year			
	THE FOOTPRINT OF THE WATER CYCLE CALCULATOR BY OCCS and/or TENV DEP. - 3 year	TOTAL FOOTPRINT OF THE WATER MANAGEMENT CYCLE: APPLYING THE MOST EFFECTIVE VALUE BETWEEN: (6 & 7) and 8										0,00	kWh/year	0,00	kg CO2/year	
	FOOTPRINT OF THE WATER MANAGEMENT, 10 YEARS CYCLE	TOTAL kwh/year										0,00	kg CO2/10 years			
	LINK TO LOCCC	ENERGY MANAGEMENT, USER/LEVEL, PUBLIC SPACE * (1)	FROM THE NETWORK			RENEWABLE			POWER			TOTAL kWh/year	FOOTPRINT			
	LINK TO ENV. D.	ELECTRICITY DEMAND BY LIGHTING AND TRAFFIC LIGHTS	STL LIGHT	kWh/year	TRAFFIC	kWh/year	CAPTURED	kWh/year	kWh/year	0,00	kWh/year	0,00	kg CO2/year			
OTHER ELECTRIC DEMAND		P.HOUSE/US	kWh/year	OTHERS	kWh/year	CAPTURED	kWh/year	0,00	kWh/year	0,00	kg CO2/year					
ESTIMATED DEMAND FOR PUBLIC SPACE BASED ON BENCHMARK * (11)		TOTAL	kWh/year	TOTAL	0,00	kWh/year	TOTAL	0,00	kWh/year	0,00	kWh/year	0,00	kg CO2/year			
FOOTPRINT OF CONSUMPTION: USING THE CALCULATOR DEP. Y.M.A. - 1 year		TOTAL kWh/year										0,00	kg CO2/year			
LINK TO LOCCC	FOOTPRINT OF ENERGY MANAGEMENT, THE PUBLIC SPACE/INFRASTRUCTURE'S LIFE SPAN: APPLYING THE MOST EFFECTIVE VALUE BETWEEN 11/12	TOTAL kWh/year										0,00	kg CO2/year			
	ENERGY MANAGEMENT IN THE DAILY LIFE, DEMAND AND CONSUMPTION, CTE - HE-0/NE-1 * (4)	DEMAND	ELECTRICITY	kWh/year	GAS * (10)	kWh/year	RENEWABLE/GEOTHERMAL/BIOGAS...	kWh/year	SOLAR FACT	kWh/year	TOTAL CAPTURED	0,00	kWh/year	0,00	kg CO2/year	
	PRODUCTION / RECOVERY	PV	kWh/year	APPARANCES CONSUMP	kWh/year	DRP - DISTRICT/TRAFFIC - EOLIC ENERGY	kWh/year	AR COND. CONSUMPTION	kWh/year	ENTRAPP / RECOVERY	kWh/year	TOTAL PRODUCTION	0,00	kWh/year	0,00	kg CO2/year
	HEAT LOAD	CH/WH2	kWh/year	APPLIANCES CONSUMP	kWh/year	AR COND. CONSUMPTION	kWh/year	LIGHTING CONSUMPTION	kWh/year	TOTAL CONSUMPTION	0,00	kWh/year	0,00	kg CO2/year		
	ESTIMATED DEMAND FOR BUILDING REFERENCE - CTE	REFURBISHMENT/REMODELING/REUSE - WING	TYPE/200	NEW BUILT	TYPE	EFFICIENCY IMPROVEMENTS	kWh/year	0,00	kWh/year	0,00	kg CO2/year					
LINK TO LOCCC	ESTIMATED DEMAND FOR BUILDING REFERENCE - CTE	REFURBISHMENT/REMODELING/REUSE - WING	TYPE/200	NEW BUILT	TYPE	EFFICIENCY IMPROVEMENTS	kWh/year	0,00	kWh/year	0,00	kg CO2/year					
	COLLECTED/LIGHT... CONSUMPTION	kWh/year	HFC CO2 EMISSIONS	kgCO2/year	CO2 ACS EMISSIONS	kgCO2/year	CO2 LIGHT EMISSIONS	kgCO2/year	0,00	kWh/year	0,00	kg CO2/year				
	PROJECTED TRANSMITTANCE	LW	US	UC	F	MINIMUM SOLAR CONTRIBUTION ACCORDING TO LOCAL REGULATION	kWh/year	0,00	kWh/year	0,00	kg CO2/year					
	THE ENERGY MANAGEMENT FOOTPRINT, THE BUILDING'S LIFE SPAN: APPLYING THE MOST EFFECTIVE VALUE BETWEEN 14/15	TOTAL kWh/year										0,00	kg CO2/year			
	FOOTPRINT OF THE ENERGY MANAGEMENT	TOTAL kWh/year										0,00	kg CO2/year			
LINK TO LOCCC	FOOTPRINT OF THE ENERGY MANAGEMENT, 10 YEARS CYCLE	TOTAL kWh/year										0,00	kg CO2/10 years			
	THE CO2 WORKSHEET - 1 of 2 - URBAN PLANNING FOOTPRINT, EMISSION SAVINGS REPORT AND THE COMPENSATIONS FOR "URBAN GREEN"															
	LINK TO ENV. D.	URBAN PLANNING FOOTPRINT, THE RESIDENTIAL DENSITY, MOBILITY, WATER AND ENERGY CONSUMPTION, CO2 EMISSIONS * (3)	FOOTPRINT * (7) (8)													
		RESIDENTS	NUMBER/HECT	URBAN AREA	HE	DEVELOPMENT	HE	EXTENSIVE	HE	OUT/UP	HE	LANDSCAPED AREA	HE			
		TOTAL PUBLIC SPACE SURFACE	m2	MODAL SHARE: MOBILITY IN %	PRIVATE VEHICLE	PUBLIC TRANSPORT	HE	GARDEN/PARK	m2	WALKING / CYCLING	HE	CLEAN VEHICLE (E.G. ELECTRICITY...)	m2			
USEFUL TO THE ELDERLY, DISABLED		%	PLAYGROUND	INCLUSIVE	%	THERAPEUTIC	%	LEISURE/RECREATIONAL/SPORTS	%	PEDAGOGIC	%					
LINK TO LOCCC	ESTIMATED DEMAND FOR URBAN PLANNING REFERENCE * (11)	CALCULATING GHG EMISSIONS IN URBAN PLANNING WITH THE DEP.7 and ENVIRONMENT GEN.CAT.Y CALCULATORS										kWh	kg CO2			
	TOTAL FOOTPRINT OF URBAN PLANNING	TOTAL kWh/year										0,00	kg CO2			
	FOOTPRINT OF URBAN PLANNING, 10 YEARS CYCLE	TOTAL kWh/year										0,00	kg CO2/10 years			
	REPORT ON THE SAVINGS AND OFFSETS IN CO2 EMISSIONS ASSOCIATED TO THE BUILDING'S PUBLIC SPACE AND INFRASTRUCTURES LIFE SPAN * (1), (2), (3), (5), (5)	TOTAL kWh/year										0,00	kg CO2/year			
LINK TO DAP_C	EMISSIONS SAVINGS BY DIMINISH THE NUMBER OF POLLUTANT VEHICLES, CHANGING SECTION AND MORPHOLOGY OF THE WAY AND ENCOURAGE THE PUBLIC TRANSPORT	TOTAL kWh/year										0,00	kg CO2			
	EMISSIONS SAVINGS BY REUSING PRE-EXISTING, SOIL THAT REMAINS ON SITE, BASE AND/OR SUBBASE PAVEMENTS, STRUCTURE AND/OR FAÇADE, PROMOTING BIODESIGN...	TOTAL kWh/year										0,00	kg CO2			
	SAVING EMISSIONS BY ECODESIGN, MATERIALS RECOVERY, RECYCLED AND REINCORPORATED WASTE, ENVIRONMENTAL IMPROVEMENTS OFFERED BY THE CONTRACTOR OF WORKS * (7)	TOTAL kWh/year										0,00	kg CO2			
	EMISSIONS SAVINGS BY REDUCING THE DEMAND, BY REUSING/REFURBISHMENT/REGENERATING: APPENDIX A	TOTAL kWh/year										0,00	kg CO2/year			
	REPORT ON THE SAVINGS AND OFFSETS IN CO2 EMISSIONS ASSOCIATED TO LIFE CYCLE	TOTAL kWh/year										0,00	kg CO2/year			
LINK TO CREAT	NATURAL CO2 SINKS	CONTRIBUTION OF VEGETATION, STORAGE, DEGRADATIVE AND CO2 UPTAKE / CREAF	SPECIES OF TREES	TYPE	HE	CO2 STORAGE	kgCO2	CO2 KIDNAPPING	kgCO2/year	0,00	kg CO2/year					
	TOTAL 3.1 - SAVINGS FOR STORE AND KIDNAPPING CARBON EMISSIONS * (5)	BUSHES	TYPE	HE	CO2 STORAGE	kgCO2	CO2 KIDNAPPING	kgCO2/year	0,00	kg CO2/year						
	OFFSETS IN CO2 FOOTPRINT	LIPOULTERY	TYPE	m2	CO2 STORAGE	kgCO2	CO2 KIDNAPPING	kgCO2/year	0,00	kg CO2/year						
	TOTAL OFFSETS IN CO2 EMISSIONS	TOTAL CO2 STORAGE										0,00	kg CO2/year			
	TOTAL OFFSETS IN CO2 EMISSIONS / 10 YEARS CYCLE	TOTAL CO2 KIDNAPPING										0,00	kg CO2/10 years			
TOTAL FOOTPRINT	TOTAL CARBON FOOTPRINT - CO2										0,00	kg CO2/year				
	TOTAL CARBON FOOTPRINT - CO2 - 10 years CYCLE										0,00	kgCO2/10 years				
	REPORT ON THE CARBON FOOTPRINT OF THE PROJECT, when calculating ASBUILT										kg CO2/year					

(1)- YOU CAN MAKE THE CALCULATION QUANTITY AND MANUALLY, ADDING IMPACTS USING THE OPEN DATABASE "BIOCIC 2014" THE CO2 / CO2EQ OR IN REGISTRATION OF DAYS DATES THROUGH USING THE ATTACHED LINKS
 (2)- YOU CAN MAKE THE CALCULATION QUANTITY AND MANUALLY, ADDING IMPACTS USING THE "COCC" CALCULATOR WITH ATTACHED LINK
 (3)- YOU CAN MAKE THE CALCULATION QUANTITY AND MANUALLY, ADDING IMPACTS USING THE "ENVIRONMENTAL DEP." CALCULATOR WITH ATTACHED LINK
 (4)- YOU CAN MAKE THE CALCULATION QUANTITY AND MANUALLY, ADDING IMPACTS USING THE "LODER-CALCENET" CALCULATOR WITH ATTACHED LINK
 (5)- YOU CAN MAKE THE CALCULATION USING THE "CREAF" CALCULATOR WITH ATTACHED LINK
 (6)- ONLY WHEN THE DISTANCE IS OVER 30 km, THE CALCULATION CAN BE MADE USING THE CALCULATOR OF THE "COCC" IN THE ATTACHED LINK
 (7)- IN THE ABSENCE OF FOOTPRINT ASSOCIATED WITH DRINKING WATER, AGGREGATE TO MAINS WATER SUPPLY WITH THE CONVERSION FACTOR OF "COCC"
 (8)- ONLY MAINS WASTE, WITH THE CONVERSION FACTOR OF "COCC"
 (9)- FOLLOW PATTERN FOR ECODESIGNED MATERIALS "POSITIVE REPORT"
 (10)- COMMISSION FROM M3/YEAR WITH THE CONVERSION TABLE OF "COCC" INCLUDED IN "POSITIVE REPORT"
 (11)- STANDARD DEMAND AT DEVELOPMENT / PLANNING IN PROJECTS WITH TECHNIQUE, MATERIAL, LIGHTING AND TRAFFIC LIGHTS STANDARD

TABLE FOR ENERGY CONVERSION INTO CO2eq EMISSIONS TO ATMOSPHERE			
ELECTRICITY FROM THE NET:	0,248 kg CO ₂ /kWh	MIX MAINLAND ELECTRICITY, GROSS PRODUCTION 2013	
WATER:	NET TLL, BENCHMARK AMB : 0,77 kWh/m3	CO2:	...m3 X 0,77 kWh/m3 X 0,248 kg CO ₂ eq/m ³



THE SUSTAINABILITY, THE ADDED VALUE

THE SUSTAINABILITY SURVEY		a	5	b	5	c	5	d	6	e	5	f	5	g	4	h	6	i	8	j	5	k	8	l	4	m
ECO-EFFICIENCY IN THE MATERIALS AND CONSTRUCTION SYSTEMS		a	b	c	d	e	f	g	h	i	j	k	l	m												
CREAF	1	SUSTAINABLE/ENVIRONMENT/QUALITY OF AIR AND WATER IN PUBLIC SPACE/THERMAL COMFORT/LIGHTING AND SOUND												BRIEF SATISFACTION OF THE LOCAL RULES FOR NOISE AND VIBRATION												
	2	ACOUSTIC ATTENUATION AND REDUCTION OF HEAT ISLAND, BY PLANTING FUNCTIONAL PLANT SPECIES												BRIEF												
	3	REDUCTION OF HYDRIC DEMAND WITH RETAINING WATER AND SUSTAINABLE DRAINAGES												BRIEF												
	4	IMPROVING AIR QUALITY, PROMOTING PUBLIC TRANSPORT GAS/ELECTRICITY												BRIEF												
	5	HEALTH PREVENTION / AVOID EXPOSURE TO ELECTROMAGNETIC FIELDS												BRIEF												
L'OCCE	6	STREET LIGHTING EFFICIENCY IN TO AVOID LIGHT POLLUTION												BRIEF COMPLIANCE WITH REGULATIONS												
	7	HEALTH PREVENTION / AVOID EXPOSURE TO ELECTROMAGNETIC FIELDS												BRIEF												
	8	STREET LIGHTING EFFICIENCY IN TO AVOID LIGHT POLLUTION												BRIEF COMPLIANCE WITH REGULATIONS												
LCCA	6	ECONOMIC SUSTAINABILITY						INVESTMENT IN ENERGY EFFICIENCY						INVESTMENT IN QUALITY, F												
	7	LCCA, COSTING OF THE LIFE SPAN						EFFICIENCY IMPROVEMENTS, SYSTEMS						RETURN ON INVESTMENT/ROI												
	8	FINANCIAL PLANNING FOR THE BUILDING'S LIFE SPAN, PUBLIC SPACE, INFRASTRUCTURE						PLANNING RENOVATION OF SYSTEMS, 1 CYCLE						PLANNING CHANGES OF USE, 1 CYCLE												
HADES	9	SOCIAL SUSTAINABILITY												BRIEF												
	10	ACCESSIBILITY, CONNECTIVITY AND INDUCED MOBILITY / MIX MODAL												BRIEF												
	11	WELLBEING / INDOOR ENVIRONMENTAL QUALITY / NATURAL LIGHTING PROFIT												BRIEF												
VERDE	12	TRACEABILITY, CHECKS												BRIEF												
	13	TRANSPARENCY / CHAIN OF CUSTODY / STEWARDSHIP												BRIEF												
	14	CTE, IMPROVEMENTS IN BASIC SERVICES												BRIEF												

* (3) FILL THE BOX WITH THE NUMBER OF SUSTAINABILITY CATEGORY, ADDED VALUE. (Eq 1.4.7.32)

BACK TO MAIN MENU

THE POSITIVE ENVIRONMENTAL REPORT

THE POSITIVE REPORT		DISPLAY OF THE AUTOMATIC CALCULATION OF POSITIVE											
A.M.B. CLIMATE ZONE: C2 / h: U-250m													
RESIDENTIAL BUILDING WITH ENERGY EFFICIENCY CERTIFICATION / reference building													
CERTIFICATION OF ENERGY EFFICIENCY FROM PROPOSAL													
DEMAND FOR BUILDING REFERENCE													
TRANSMITTANCE PROPOSAL/ UMI-FACADES AND WALLS/ UG- GROUND FLOOR/ UG- AN													
BUILDING SERVICES / TRANSMITTANCE LIMITS IN WALLS, FLOORS AND ROOF AND SOLAR FACED SURFACES													
DISPLAY OF COMPARATIVE CALCULATION PROJECT/CONSTRUCTION STANDARD													
PUBLIC SPACE/ INFRASTRUCTURE / URBAN PLANNING: STANDARD ENERGY CONSUMPTION													
ENERGY OBTAINED FROM SUPPLY NETWORK													
E. RENEWABLE													
POSITIVE REPORT SUMMARY													
ENERGY EFFICIENCY IMPROVEMENTS													
POSITIVE REPORT PROPOSAL													
SOLAR HEDGING													
SOLAR HEDGING PROPOSAL													
BUILDING EMISSIONS REFERENCE													
CO2 EMISSIONS PROPOSAL													
THE RESULTS OF THE POSITIVE CONTRIBUTION TO 202020													
ENERGY CONVERSION FACTORS IN CO2 EMISSIONS TO ATMOSPHERE TABLE													
ELECTRICITY OF THE NETWORK													
Electricity mix península, gross output in 2013													
0,248 kgCO2/kWh													
WATER													
FUEL CONSUMPTION													
NATURAL SINKS OF CO2, THE C.R.E.A.F. THE U.A.B.													
Urban													
EXAMPLE: CALCULATION OF EMISSION SAVINGS BY INCORPORATING 20% OF THE RECYCLED AGGREGATE / CRUSHED ON SITE													
D060P01 - HORMIGÓN SINE ADITIVOS DESIGNADO POR DOSIFICACION DE CEMENTO													
F2R6_01 - CÀRREGA I TRANSP													
Càrrega amb mitjans mecànics i transport de res													
D060P01 m3 Formigó de 200 kg/m3, amb una proporció en volum 1:3:6, amb ciment portland amb filler calçari CEM II/B-L 32,5 R i granulat de pedra granítica de													
Consumo													
Peso													
Coste													
Emisión CO2													
ARIDO REICLADO INCORPORADO 20%													
AHORRO emisiones													
RESIDUOS AHORRADOS													
ahorro emisiones por el transporte de los residuos													
Residuos ahorrados: 400 Kg/m3													
Residuos ahorrados: 2.500 Kg/m3													
Residuos ahorrados: 15% % residuo no transportado													
Residuos ahorrados: 15% % Factor esponjamiento = 19													
Residuos no transportados: 19 %													
TOTAL SAVINGS TO INCORPORATE RECYCLED WASTE AND SAVE EMISSIONS: 3.93 kg CO2 / M3 + 9.26 kg CO2 / M3 - 3.18 kg CO2 / M3 = 9.61 kg CO2 / M3													
BACK TO MAIN MENU													

THE OPEN/PUBLIC CARBON FOOTPRINT CALCULATORS

L'HDC



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Renovation of non-profit social housing to CO₂ neutral buildings on Active House level

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Abstract:

The Poorters of Montfoort in Netherland are the first non-profit social housing renovated to Active House principles. The Active House principles forms the basis for the refurbishment, where comfort, energy and environmental issues are equally balanced in-between each other. The houses are owned by GroenWest which offer their customers attractive, affordable and sustainable housing in a pleasant environment. It has been a requirement to make the refurbishment affordable for ordinary people and to keep the rental fee at an affordable level. It is managed to reach a refurbishment and modernization that meet the highest demand for sustainable buildings, by focusing on comfort, energy and environment. Due to its attractive location, and because the homes are spacious with high future value, the housing corporation GroenWest decided to bring ten houses to an Active House level and give the residents a healthy and comfortable indoor climate with more daylight and fresh air.

Key words:

Zero Carbon Buildings, Healthy indoor climate, Affordable refurbishment, Active House design, Non-profit Social Housing

1.0 Challenges

There are 25 billion m² of useful floor space in the EU27, Switzerland and Norway, with approximately 75% of those being in the residential sector including, single family houses, row houses and multi-story buildings.

The age of the building stock varies throughout Europe, however approximately half of the buildings are constructed during the period from 1960 to 1990 (fig 1), and a large number of those houses are now ready for modernization and need an energy and indoor climate renovation, in order to meet current standards for energy efficiency and comfort.

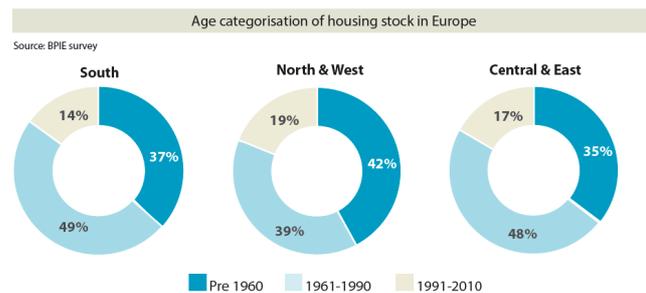


Figure 1: Age of European Building Stock (Source BPIE)

1.1 Modernization with focus on Comfort Energy and Environment

Modernization of the building stock are often based on a focus to reduce use of energy for the users of the buildings and thereby a focus on the payback of the energy savings. However buildings and especially residential buildings are made for people to live, play and work in, and as people spend 90% of their time inside in buildings a modernization focus on the residential building stock must include a wider scope and include comfort and environment perspective.

The Active House vision proposes a target framework on how to design and renovate buildings that contribute positively to human health and wellbeing by focusing on the indoor and outdoor environment. An Active House is evaluated on the basis of the interaction between energy consumption, indoor climate conditions and impact on the external environment.

De Poorters van Montfoort is a refurbishment initiative based on the Active House principles. It involves a range of partners from the building industry and housing sector. Their vision was realized in the Dutch town of Montfoort, but it is relevant everywhere, where existing buildings are in need of change: renovation is not just about maintaining the past – it is a chance to prepare for the future. The Poorters van Montfoort is an important example for the Netherlands where there is an stock of over two million row-houses in tehe social sector. most of which need a refurbishment in the next two decades.

1.2 Ownership

Throughout Europe, the social housing is typically owned by the public sector, however there is an increasing trend towards non-public involvement as is the case in Ireland, England, Austria, France and Denmark while in the Netherlands social housing is fully owned by private sector. The ownerships of social housing is often a barrier for modernization and is a challenges that need to be addressed in order to initiate and utilize the energy and CO₂ savings potential mentioned above

The social housing De Poorters van Montfoort are owned by GroenWest which is a non-profit socially engaged housing corporation managing 12.000 homes. They offer their customers attractive, affordable and sustainable housing in a pleasant environment and they set the requirement to themselves; to make the refurbishment affordable for ordinary people and to keep the rental fee at an affordable level.

1.3 User perspective of modernization

The renovation of the existing building stock can revitalize the design and upgrade the appearance of the buildings and create a longer living period with less environmental impact. But, most importantly, it can change the lives of the residents. Edwin Hamelink living in De Poorters van Montfoort is one of them. After living in Poorterstraat for 18 years with his wife and four children, he has experienced both the shortcomings of the past and the new possibilities of the future: *“It would be fair to say that comfort was very bad before the remodelling. That has changed now,”* he says. He especially appreciates how the modernization has improved the daily life of his family. *“We are amazed by the extra space in the attic. Thanks to this extension, we now have four bedrooms. That is great for a family with four children,”* explains Edwin Hamelink. The transformation has left him looking forward to living in Poorterstraat for a long time: *“It is truly a brand new start that will hopefully go on for many years.”*

The Active House renovated buildings in De Poorters van Montfoort have at the same time attained energy label A++ and the renovation is expected to reduce the energy costs per house by around 130 euro a month, which is more than the rent increase needed to pay for the renovation.

2.0 Modernization of Poorterstraat district of Montfoort

The Poorterstraat district of Montfoort include 92 single family row houses, which have provided affordable homes for local families since the 1970s. After almost 40 years, the houses had become worn and uncomfortable by the standards of the 21st century. When the residents had their say, they came up with a list of shortcomings: draughty, gloomy, soaring energy costs and a general lack of space.

The owner, housing association GroenWest, decided to embark on a major renovation which involved all 92 houses, but ten homes were chosen for a sustainable transformation of greater scope.

The architect group BouwhulpGroep was given the task of implementing the Active House principles in the construction of the Poorterstraat houses. They decided to add extra space and light by making use of the houses’ unutilised attics. Every attic was enlarged and became an entity on its own, resulting in a new room and a rooftop terrace.



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Figure 2 Project before and after modernization

2.1 Evaluation

One of the 10 dwellings has been evaluated based on the 9 parameters in the Active House Radar and as the dwellings all have the same layout, have been renovated with the same materials etc. the evaluation results are representative for all 10 dwellings.



The project has been evaluated before and after the modernization and the situation after modernization has been evaluated for a full active house evaluation with 9 parameters, whereas the situation before is based on a limited evaluation. The evaluations are based on drawings and technical documentation and will be followed up by monitoring and interviews with the inhabitants. In the following chapters the design and performance for the 9 parameters are described. The evaluation shows that the performance of the house has increased on thermal comfort as well as on the energy issues, which also was a driver for the

development of the modernization.

Figure 3 Active House Radar

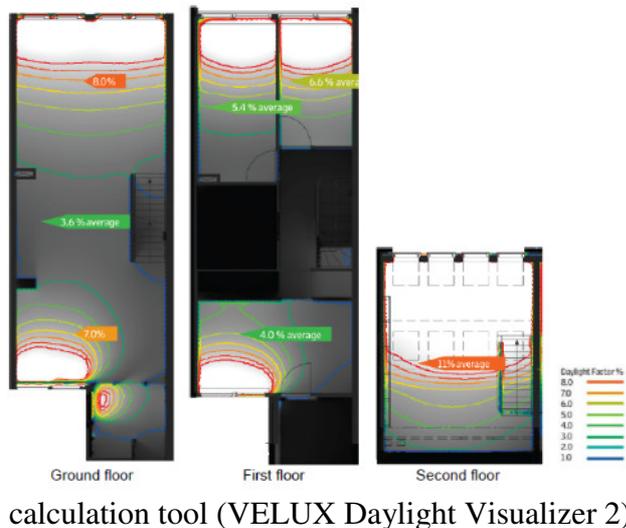
2.2 Comfort

We know that up to 30% of the building mass do not contribute to a good indoor climate and that many buildings suffer from “Sick Building Syndrome” and as people spend 90% of their time indoors; the quality of the indoor climate has a considerable impact on our health and comfort. A good indoor climate is a key quality of an Active House and it should be an integrated part of a modernization project, which it also has been in the modernization projects in Poorterstraat district of Montfoort.

2.2.1 Daylight

Adequate lighting and especially well-designed daylight penetration provide an array of health benefits to people in buildings. High levels of daylight and an optimised view out positively influence people's mood and well-being. Rooms with an average DF of 2% or more are considered adequately daylight, and a room will appear strongly daylight when the average DF is above 5%.

At De Poorters van Montfoort, the large windows and careful selection of bright indoor surfaces that reflect daylight deep into the spaces, in combination with the position of the stairs, has ensured good daylighting with increased daylight factors. However the daylight factors in the ground floor habitable room has only changed significantly due to the fact that window dimensions and positioning in the ground floor habitable rooms after the renovation are very close to the dimensions before the renovation. Some window dimensions in ground floor are increased, but since the geometry of the building is kept, the daylight factors in the back of the rooms are not changed significantly and thereby the daylight factor here is not changed. It is however 3,5%, which are good daylight conditions and allow for the second best class in the Active House evaluation.



The figure show the distribution of daylight and the daylight factors in the different rooms of one house and it can be seen that in large parts the building the daylight factor is above 8%. More importantly, the average daylight factors in the rooms (indicated in the diagrams) are between 3.6% and 11%, leaving the building well day lighted. The darker room on second floor is the bathroom without access to direct daylight. This room could have performed better by us of daylight tunnels. The daylight factor has been calculated with a dynamic daylight

calculation tool (VELUX Daylight Visualizer 2).

2.2.2 Thermal Comfort

The thermal comfort of the building has to be evaluated for both summer and winter conditions. With the development of better insulated and tight buildings, the risk for overheating during summer is increasing and becoming an important issues even in cold regions with medium summer conditions like Holland, England, Denmark etc.

In De Poorters van Montfoort an establishment of a hybrid ventilation strategy solves this, and it include use of mechanical ventilation for winter and natural ventilation for summer. The natural ventilation is established through strategically positioned roof windows and façade windows on all floors of the building, from ground level right up to the roof ridge. On the one hand, they provide horizontal cross-ventilation on the different floors; on the other, opening the roof windows on the top floor creates a (vertical) chimney effect around the open stairwell that channels the stale air up from both the floors below. This strategy ensures, above all, that there is some welcome night-cooling in the houses in the summer. In winter, a mechanical ventilation system with heat recovery and CO₂ sensors guarantees a comfortable and healthy circulation of air.

The thermal comfort is simulated in VELUX Energy and Indoor Climate Visualizer, which is a dynamic simulation tool based on EN 15251:2007 and used to determinate hourly values of indoor operative temperature at room level for both summer and winter. The software calculates the operative temperature and the corresponding outdoor temperatures for each hour. Atelier, living room, master bedroom and 2 small bedrooms are evaluated. When using natural ventilation the adaptive temperature limits are used in the summer months. This means that the maximum allowable temperature inside is linked to the weather outside: limits go up during warmer periods.

The simulations shows that the modernization of the house meet the highest requirement to indoor comfort during summer ($0,33 \times$ mean out door temperature + 20,8 °C) with the limit that the temperature shall be met for 95% of the occupied time in the summer. The maximum heating demand for the winter period is lower than the installed capacity of the room heating system, and thereby it's proven that the heating system is capable of maintaining a room temperature of 21 °C throughout the heating season.

A better thermal comfort was one of the main wishes from the inhabitants. The modernization of the house moves the classification of the house from a level 4 to a level 1 in the Active House Radar evaluation, meaning that the indoor comfort level for both winter and summer has increased and created a better and healthier indoor comfort for the family living in the building.

2.2.3 Air quality

The ventilation strategy mentioned above also secure a good air quality with a maximum CO₂ levels in the rooms in the range of 325 to 350 ppm above the outdoor CO₂ concentration – far below the 500-ppm threshold required to achieve level 1 in the Indoor Air Quality parameter.

Before the renovation, the building had a large uncontrolled leakiness, which gave a high and uncontrolled air exchange, and after the renovation the façade has reached high airtightness, with controlled fresh air supplied through the hybrid ventilation system. Thereby the air exchanges has not been improved by the renovation, but has become controlled and thereby energy efficient.

2.2 Energy

Building legislation includes requirement to primary energy use, as the requirement takes into consideration primary energy factors and the energy supply systems. However it is the energy demand (final energy) that sets the level of the daily use of kWh and costs for the users of the house and therefor it is a highly relevant figure to compare for the house owners.

2.2.1 Energy demand (final energy)

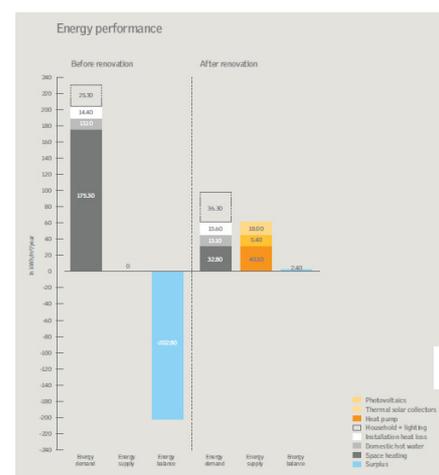
At De Poorters van Montfoort, all parts of the building envelope were insulated. An entirely new roof was added; the existing facades received new insulation and a new brick facing, and the old, poorly insulated windows with their thin, aluminum frames were replaced with new, triple-glazed models with timber frames. The new heating system in the houses uses neither gas boilers nor chimneys. Instead, a heat pump heats each house.

The energy demand in the houses has been reduced to 62 kWh/m² with a heat demand on 33 kWh/m² which is more than a factor of five due to the renovation. This brings the building to the second best class for energy demand and close to new buildings level.

2.2.2 Renewable energy

To supply the houses with energy, a 19.5 m² photovoltaic array and 4.5 m² of solar thermal collectors has been installed on the roof of each building.

The PV on the roofs supply the building with the necessary energy for the heat pump which is producing 40,5 kWh/m² and with the solar thermal system producing 5,4 kWh/m², those two solution fully supply the building with heat. Supplementary to this the PV on the roof produce 18 kWh/m² which is used for the remaining technical equipment, giving an annual surplus on energy production of 2,4 kWh/m².





Thereby the renewable energy system can fully support the building with the energy needed and bring it to the highest class of Active House with 100% supply of renewable energy either on the building, the plot or in the energy system.

2.2.3 Primary Energy

The primary energy factors depend on local and national conditions. At De Poorters van Montfoort the primary energy reach a level of 70,9 kWh/m². However as all the energy is produced within the building boarder, the building is fully self-supplying with energy and thereby the annual primary energy factors reach zero energy level.

The modernization moves the evaluation from the lowest to the highest level for Active House.

2.3 Environment

The environmental challenges are growing and it is highly relevant to start an evaluation on how buildings perform during their life time and which foot print buildings has. Active house evaluates environment on 3 levels, Environmental loads, Water consumption and Sustainable construction.

2.3.1 Environmental Impact

To evaluate the environmental impact of the houses in further detail, engineering office Grontmij performed a life cycle analysis (LCA).

The estimated service life of the building is assumed to 75 years and all major building components have been considered. The LCA results for each building component have been multiplied by a safety factor of 1.1 to compensate for materials in the building components, which is not included in a simplified LCA calculation. The life stages included production, operation of the building, replacement of building materials and end of life of building materials and components. The environmental impact data of materials and components are generic data from the German material database Ökobau.dat and the European material database ESUCO.

A closer look at the evaluation reveals that approximately 80% of the overall primary energy use and CO₂ emissions of the building are caused during its operation phase, and only 20% by the materials production and construction activities. The annual non-renewable (PE) value is 122.6 kWh/m² and global warming potential (GWP) is 31.4 kg CO₂-eq./m²a

The same percentages occurs for Acidification potential (AP) and Ozone depletion potential (ODP) with 80% load during the operation, whereas Photochemical ozone creation potential (POCP) and Eutrophication potential (EP) with different with 55% during operation and 45% during production.

This brings the building to a medium level on the environmental load in the Active House evaluation

2.3.2 Fresh water consumption



In Netherlands the average household water use is around 46,7 m³ per capita per year and because Holland has a good infrastructure and a sufficient stock of fresh water of high quality domestic fresh water isn't an issue here. Therefore no specific initiatives has been used in the modernizations the water consumption is classified at the lowest Active House level

2.3.3 Sustainable construction

In future buildings, it will become ever more important to specify sustainable materials, and in Holland it will be an obligation from 2015. The recyclable potential of the material used in De Poorters van Montfoort has been evaluated to be 63% for all the main products and materials. The evaluation include 90% renewable potential for insulation and zink, 75% for brigs, gypsum boards, 50% for wood, glass and 0% for cement, concrete, and steel material.

All timber used in De Poorters van Montfoort is either FSC or PEFC certified.

With the above focus on sustainable construction, the above reach the best level in the Active House evaluation.

3. Potential and perspective

Studies by among others the Danish research institute for buildings SBI and the European Building Research institute shows that energy savings between 35% and 70 % are possible in the existing building stock. Thereby the Montfoort project reach the highest level of savings, with energy use of 202 kWh/m² before renovation and through the renovation and modernization it was reduced with 140 kWh to 61,5 kWh/m², approximately 70%. With integration of energy supply, it reached a primary energy balance of 2,4 kWh/m².

Scaling the energy savings on app 140 kWh/m² to all European residential buildings build between 1960 and 1990 the potential for savings are close to 1.300.000 GWh/annually. Such savings can be reached parallel to the development of better healthier and more environmental friendly buildings as shown in the case with this paper.

The next initiatives should be to monitor and follow the development of the modernized buildings to identify if the buildings perform as calculated and thereby to prove that the specific savings are reached and thereby that the global European saving potential can be reached.

The pace of energy improvement in the Dutch non-profit housing sector

Speakers:

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Abstract: *The existing housing stock is crucial in order to meet the energy saving targets set in the Netherlands and the EU as a whole. The non-profit housing sector in the country plays a major role as it represents 34% of the total housing stock. The focus of this paper is to analyse the current energy efficiency state and the energy renovation pace of the sector. The data necessary for the research are drawn from a monitoring system, SHAERE, which contains data about the energy performance of 60% of the dwellings of the non-profit rented housing stock of 2013. The methodology followed is based on quantitative data analysis of physical properties regarding energy efficiency, general dwelling characteristics and energy consumption of the households. The results of this research provide insight in the progress of the energy efficiency of the existing residential stock.*

Keywords: *Energy efficiency, renovation, monitoring, housing, the Netherlands*

Introduction

The building sector and specifically the existing housing stock are crucial in order to meet the energy saving targets set in the Netherlands and in the EU as a whole [1][2]. At the same time, existing dwellings are not the first priority of several policy measures in achieving energy efficiency goals in the residential sector [3]. However, existing buildings account for approximately 40% of the energy consumption in the European Union and are responsible for 30% of the CO₂ emissions [4]. A large percentage of this energy consumption comes from the residential sector, as dwellings consume 30% of the energy of the total building stock [5]. As reported on 2012 by the Statistics Netherlands, based on the analysis of 2009, households in the country are responsible for 425 PJ of energy consumption.

Policies applied in the Netherlands correspond to several national and European goals. In 2008 the Energy Performance of Buildings Directive, EPBD, of the EU was implemented in the Netherlands. Under this directive, all member states must establish and apply minimum energy performance requirements for new and existing buildings, ensure the certification of building energy performance and require the regular inspection of boilers and air-conditioning systems in buildings. Moreover, the revised Directive of 2010 requires member states to also ensure that by the end of 2020 all new buildings are 'nearly zero-energy buildings' [6].

Energy renovations in existing dwellings offer unique opportunities for reducing the energy consumption and greenhouse gas emissions on a national scale concerning the Netherlands but also on a European and global level. Although there have been initiatives for energy renovations of the dwellings in the Netherlands, the assessment and monitoring of the pace of



these renovations is lacking. However, it is necessary and can provide valuable information concerning the nature and the future potential of the measures applied. The main research question of this paper is what the energy improvement pace in the Dutch non-profit housing sector has been over the last years.

In the second section an introduction to the social housing and the energy efficiency requirements in the country will be presented. The third section goes into detail about the data used and the methods followed. In the fourth section the results will be presented and in the fifth section conclusions will be drawn and steps for future research will be discussed.

Non-profit rented housing and energy efficiency requirements

Housing tenure differs across Europe and no common definition for the non-profit housing sector is used. However, there are three common elements present across European non-profit -social- housing sectors: a mission of general interest, offering affordable housing for the low-income population and the realization of specific targets defined in terms of socio-economic status or the presence of vulnerabilities [7].

In the Netherlands, where the focus of this study lies, the non-profit housing sector counts 2.4 million homes, which is 34% of the total housing market [8][9]. This is a unique situation as the Netherlands have the highest percentage of non-profit housing sector in the European Union. The non-profit housing organizations have several goals and criteria to fulfil [10]. Energy savings and sustainability seem to be high on the agenda [8]. According to the Energy Saving Covenant for the Rented Sector (“CovenantEnergiebesparingHuursector”), the current aim of the social housing sector is to have an average energy label B. The Covenant is a voluntary agreement between, among others, Aedes, the umbrella organisation of housing associations, the national tenants union and the national government. The goal of the agreement represents an energy saving of 33% on the theoretical/predicted energy consumption in the period of 2008 to 2021 [9].

Data and methods

In 2008 after the formulation of an earlier covenant on energy saving, Aedes started a monitoring system of the dwellings called SHAERE.

SHAERE (“SocialeHuursector Audit en Evaluatie van ResultatenEnergiebesparing”) which translates in English as Social Rented Sector Audit and Evaluation of Energy Saving Results, is the official tool for monitoring progress in the field of energy saving measures for the social housing sector. SHAERE is a collective database in which the majority of the housing associations participate. The data imported include physical characteristics and installations of the dwellings in order to be used for their energy labelling. The data include: U and R_c values of the envelope elements, estimated energy consumption, CO₂ emissions, the average EI (Energy Index), the registration of the energy label and more. The variables are categorized

per property (home) and in 2013, 1,448,266 dwellings were available, representing 60% of the total amount of dwellings in the stock.

Research approach

This study presents a first analysis of the trends of the energy renovation pace in the social housing stock in the Netherlands between 2010 and 2013. First, the sample is described and, based on this description, the analysis method is presented. A considerable part of the social housing stock is included in the SHAERE database, but the number of homes differs per year. Table 1 presents the exact numbers. At the end of each year, since 2010, the housing associations report the state of their dwellings to Aedes.

Table 1: Raw data on the number of dwellings reported in SHAERE per year

Year of reporting	Frequency	Percentage of the total stock
2010	1132946	47.2%
2011	1186067	49.4%
2012	1438700	59.9%
2013	1448266	60.3%

In this study the Dutch ‘energy index’ (EI) will be tracked through the consecutive years in order to calculate the energy renovation pace based on the energy performance of the dwellings. The energy index is the official tool for measuring the energy efficiency of a dwelling and is then translated to the more known energy label, where each label corresponds to an energy index within specified boundaries.

The EI is connected to the total theoretical energy consumption related to the building, i.e. energy for heating, cooling and ventilation, and lighting of the communal areas (not for individual appliances like TV’s, computers and fridges), under the assumption of a standard use. It is important to keep in mind that the energy consumption is referred to the theoretical as previous research by D. Majcen et.al. has shown [13]. According to the norm of the calculation, it is corrected taking into account the floor area of the dwelling and the corresponding heat transmission areas, as shown in Equation 1. A shape correction is applied as well when considering the infiltration losses within space heating demand, while the air permeability coefficient depends on the buildings’ shape factor.

The energy index in the Netherlands is calculated as follows:

$$EI = \frac{Q_{total}}{155 * A_{floor} + 106 * A_{loss} + 9560}$$

Q_{total} refers to characteristic yearly primary energy use of a dwelling based on ISSO 82.3 and includes energy for space heating, domestic hot water, additional energy (auxiliary electric energy needed to operate the heating system i.e. pumps and fans), lighting, energy generation

by photovoltaic systems and energy generation by combined heat and power systems. A_{floor} refers to the area of the dwelling whereas A_{loss} to the areas that are not heated in the dwelling such as a cellar [14] [15].

In order to identify the energy improvement pace in the social housing stock we observed the whole stock for four consecutive years and tracking down the differences in the EI regarding the dwellings that are registered in SHAERE for more than one year. If a deterioration of the energy index over the years was observed, we assume this to be an administrative correction. In these cases the energy index for the years before the change has been corrected to the level of the energy index afterwards.

Results

Figure 1 presents the distribution of the energy labels of the social housing stock for four different years (2010-2013).

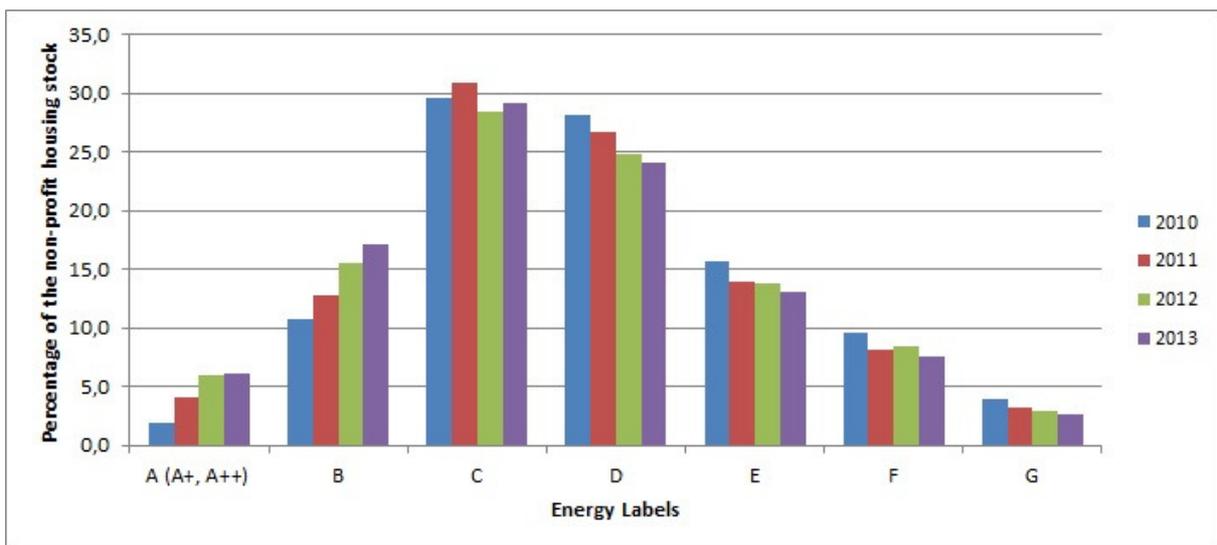


Figure 1: Distribution of the energy labels of the non-profit rented housing sector in SHAERE database

It is clear that there is a tendency of an increasing performance through the years. In the first column of the graph (A label) the A+ and A++ labels are also included. The labels denoting a relatively inefficient home (D, E, F, G) show a decline through the years whereas the ‘higher’ efficiency labels (A, B, C) show an increase. The distribution of the labels corresponds to an average energy index of 1.71 or an average label D for social housing sector in the Netherlands. In 2010 the average energy index was 1.80, in 2011 it was 1.73, in 2012 it was 1.72 and in 2013 it was 1.69 all corresponding to an average label D.

After examining the improvement pace of the stock through the years in the following table the changes of the EI and as a result of the labels are presented. In Table 2, the changes for the period of 2010 to 2013 are presented. 16.8% (258,440 of 1,537,554) had their label improved, moving up from a worse label to a better one (the sum of all dwellings above the diagonal in Table 2), while 83.2% of the pre-labels did not change label category.

Table 2: Number of pre-label changes in each label category (number of dwellings with a pre-label change: n=1.537.554)

		2010						
		A	B	C	D	E	F	G
2013	A	42925	6798	2423	2069	1335	1326	377
	B		164595	44294	13012	6617	4269	1551
	C			397335	65265	15316	5893	1906
	D				342320	38570	14312	2532
	E					180030	19163	4738
	F						106529	6674
	G							45380
Total		42925	171393	444052	422666	241868	151492	63158

The transfer of A labels from the rest of the label categories is: 4% of label B, 1% of label C, 0.5% of label D, 1% of label E, 1% of label F and 1% of label G. However, if we look carefully at the numbers the majority of the dwellings that have moved to label A comes from B, C and D label and not of E, F and G. On the contrary, the majority of the E, F and G labels have moved to D and E labels (17% of E moved to D, 14% of F to E, 8% of G to E and 12% from G to F) as shown on Table 2. The number of dwellings that have undergone major improvements (i.e. from label G, F and E to label A) correspond to 2.2% of the 258.440 dwellings that had their label improved. Additionally, following the changes, another trend is obvious. The majority of dwellings with a D label in 2010 have improved with a percentage of 16% to label C, whereas the improvement to label B is 3% and to A 0.5%.

Figure 2 presents the size of the improvements in terms of label changes.

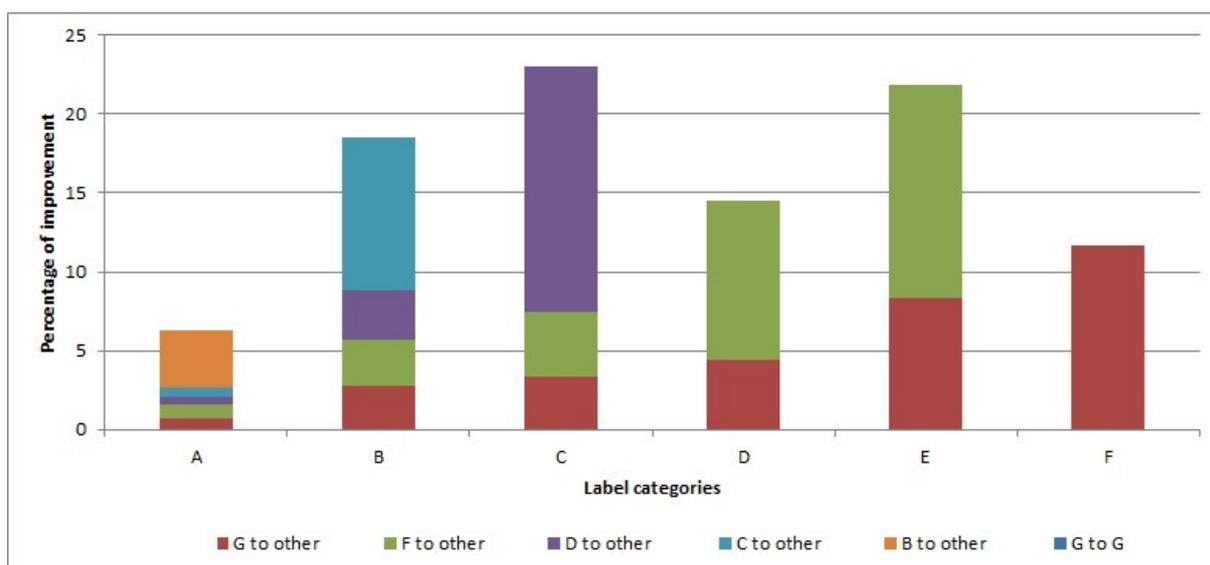


Figure 2: Improvement of labels of the non-profit rented housing sector from 2010 to 2013



The largest changes in 'label steps' can be observed among the dwellings with a G label. Most improvements, however, are relatively small (one or two steps), which is an indication of the choice of energy efficiency measures applied. The majority of the labels that improved to A label comes from B. This fact also applied to labels from C to B and from D to C respectively.

Conclusions

SHAERE has proven to be a rich database where the state of the social rented sector dwellings' are reported at the end of each year. This research was based on the dwellings' physical properties and the reported energy index in order to track the improvements from 2010 to 2013.

For the period of 2010 to 2013, the results show that, although many energy improvements have been realized, they result in small changes of the energy efficiency of the dwellings. If the goal of an average label B by 2021 is to be reached the energy efficiency measures should be strengthened as the average label of the stock in 2013 is D. The majority of the improvements correspond to small changes of the energy index and as a result of the energy label. The number of dwellings that have undergone major improvements (i.e. from label G, F and E to label A) correspond to 2.2% of the 258.440 dwellings that had their label improved. The results show that the efficacy of the measures applied so far is low.

The year by year pace of energy efficiency improvements will provide even more detailed results concerning the energy improvements pace of the Dutch social housing sector. Finally, in future research it is planned to examine which measures are applied in order to assess their efficacy in more detail.

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Session 87:

How reliable are previous level rating tools on an urban scale?

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A hybrid methodology for the environmental assessment of anthropic systems in urban areas

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Abstract: *In this paper we first review available frameworks for the environmental assessment of urban areas. Then, we present a hybrid methodology to assess the environmental impacts of anthropic systems in urban areas. It combines principles from the Urban Metabolism / Material Flow Analysis (UM/MFA), the Life Cycle Assessment (LCA) and the Environmental Risk Assessment (ERA) methodologies. Linking the UM/MFA and LCA methodologies enables the improvement of anthropic urban activities and related infrastructure in terms of multi-criteria impacts and takes into account the life cycle of the urban components. The ERA methodology then allows the assessment of the local impacts on water and soil. The description of benefits and challenges for this hybrid methodology are given through its implementation for specific examples. The findings of this study offer insights on the importance of combining the benefits of different methods for the assessment of anthropic systems in urban areas.*

Keywords: *assessment methodology; environmental impacts; decision support tool; city; urban development*

Introduction

It is estimated that more than 50% of the world's population now lives in urban areas (60 % by 2030 and 70% by 2050) [1]. This high urbanization proportion has become an increase concern for the sustainable development of the world because pollutant emissions will be concentrated in small areas (less than 1% of the terrestrial surface [1]). Moreover, the food and renewable energy production require important surfaces that are usually coming from outside of the urban areas due to the limited available space in cities. In that context, it is clear that assessing the sustainability of urban areas requires a combination of environmental information of the system (located in the urban area) but also environmental information concerning the background impacts related to processes located outside the city. This issue has brought forward the field of Urban Metabolism (UM) that concentrates on the assessment of environmental sustainability of urban activities. In a recent review of the UM field [2], the use of a number of methodologies have been identified. To cite a few: the Material Flow Analysis (MFA), the Emergy analysis and the Ecological Footprint (EF) methodologies have been used in many studies. Furthermore, results of those different case studies (cities assessment) offer a wide range of information on different sustainability issues even with a specific methodology [3]. This important variability in methodologies, framework, implementation and research question must be analyzed to propose a methodology that serves specific goals. Indeed, the starting point of any assessment should be the identification of the “need” for an urban project team, such as for example: 1) aid decision in the choice of one of the two technical solution proposed: option A versus option B for the same functionalities; 2) Labeling process: the environmental performance assessment of the project in view of labeling; 3) The identification of hot spots or investment priorities: to identify the environmental hotspots from a global perspective. In any case, the methodology should be tailored in function of the



case study type. This means that a more or less fine analysis is needed (such as, for example screening, simplified or detailed assessment), as function of the final goal of the assessment, the data availability, etc.

The goal of this work is to propose a hybrid methodology which combines the benefits of previously used methodologies for the environmental assessment of anthropic systems in urban area (UMs). In this paper, we first review available frameworks for the environmental assessment of urban areas. Then, we present a hybrid methodology to assess the environmental impacts of anthropic systems in urban areas. The hybrid methodology will be applied for specific examples. The benefits and limitations of the hybrid methodology will then be discussed, before the conclusion and proposal of future developments of this work.

State of the art

Many reviews of UM studies and related assessment methodologies have been presented in recent years (e.g. [2,3]). Most consider the Wolman's paper from 1965 [4] as a seminal work and a landmark paper, in that it took the notion of urban metabolism beyond a concept and began to create a methodology to model the UM with a quantitative approach. In the recent "Metropolitan Sustainability" book [5], authors concluded that there are two, related, non-conflicting, schools of UM studies: 1) the MFA methodology which broadly expresses a city's flows of energy or materials; 2) the Emergy analysis methodology which describes UMs in terms of solar energy equivalents flows. The MFA methodology is one of the most common approaches in UM studies. As discussed by Zhang [2], some studies are now using a network modeling approach to describe UM instead of the previously used "black-box" framework. The main benefit of the MFA methodology is that it enables the use of network modeling that allows the identification of closed-loop in material flows and the consideration of stocks. Nevertheless, the MFA methodology does not translate environmental pressures (e.g. food consumption) into impacts (e.g. land use). In order to overcome this drawback, some authors focused on impact assessment based on the LCA methodology applied to UM studies (e.g. [6]). The LCA methodology is standardized [7] and used for the environmental assessment of various products and systems. Different databases, operational guidance documents and tools have been developed for the construction sector with the principles of the LCA in mind, such as ELODIE (www.elodie-csbt.fr), NovaEquer (www.izuba.fr), NEST (www.nobatek-nest.com), etc. One of the main principles of the LCA methodology is to offer a multi-criteria environmental assessment with a life cycle perspective to describe the assessed system [7]. This broad assessment promotes global environmental performances and decreases the chance of shifting environmental pressure when one development option is chosen instead of another. The environmental impacts associated with a product/system, for each phase of its life cycle, are evaluated based on Life Cycle Inventory (LCI) flows, such as raw material consumption, energy consumption, and water consumption, and waste generation, emissions to air, soil and water. The LCA methodology considers efficiently global scale issues by using a standardized environment for given time periods and geographic scales, applying generalized modeling tools and databases. The main drawback of LCA is its inefficiency in the consideration of local impacts because of the aggregation of LCI flows coming from processes located in different geographical areas [8]. To solve this challenge, it is interesting to explore the Environmental Risk Assessment (ERA)



methodology. The relationship between LCA and ERA methods have been analyzed and new solutions combined both methodologies [9,10]. In this sense, several strategies have been proposed: replacement of generic emission data used in LCA methodology with data from ERA methodology at local scale; including source terms from ERA in LCA methodologies; using ERA assessment as ‘veto study’ (if the risk is acceptable, the evaluation can be made with the LCA methodology) [9,10].

The main benefits and drawbacks of these methodologies are summarized in table 1.

Table 1. Main benefits and drawbacks of MFA, LCA and ERA methodologies

	MFA	LCA	ERA
Benefits	Identify loops in system modeling Stocks	Multi-criteria impacts Life Cycle perspective (e.g. 50 years for buildings)	Local impacts on water and soil
Drawbacks	No impacts Limited period of study (usually 1 year)	No stocks Inefficient on local impacts assessment	No multi-criteria impacts

The hybrid methodology

The hybrid methodology presented in this work combines the strengths of three environmental assessment methodologies: the UM / MFA (for network modeling), the LCA (for multi-criteria impacts and life cycle perspective) and the ERA (for local impacts in term of water and soil pollution). Linking the UM/MFA and LCA methodologies enables the improvement of anthropic urban activities and related infrastructure in terms of multi-criteria impacts. It also helps in accounting for the life cycle effects of urban components. The ERA methodology allows the modeling of released substances into the water and soil at a local scale.

Modeling a system with the MFA methodology requires three types of information. First, the inputs and outputs flows of the system must be defined for one type of substance (e.g. water) and a specific period of time (usually one year). Second, a modular disaggregation (processes) of the system and their interactions (process flows) must be considered to identify loops that are indication of increases environmental sustainability. Finally, the stocks that are made over the analyzed period must be described to insure the conservation of mass or energy.

The LCA methodology can be summarized as the use of a Life Cycle Impact Assessment (LCIA) method on the amount of pollutant emission and natural resource extractions that are linked to the life cycle of a chosen system. This amount of emissions and extractions is expressed as Life Cycle Inventory (LCI). The LCIA considers many different categories of impacts (such as climate change, energy consumption, waste production, etc.) at a global or local scale and with different time horizons. This means that an LCI cannot be calculated from the standard system modeling of the MFA methodology which provides data for a

specific area and period of time. It requires complementary information in order to consider many substances of an unbounded period of time and areas. As stated above, the main drawback of the LCA is its inefficiency in the consideration of local impacts. The proposed solution in order to overcome this drawback is firstly to calculate the cumulated mass of each pollutant released from the concerned build area (i.e. built area in contact with water) over the life span of the considered construction product. The modeling is based on the long time leaching behavior (source term of ERA approach). Then, an impact assessment method of the LCA field is used to estimate the associated impacts. This solution offers a more representative and explicit analysis of a type of process that is usually not accurately modeled in urban area and building environmental studies.

Figure 1 summarized the different steps of the hybrid assessment methodology by describing where the MFA, LCA and ERA methodologies are used when we model and assess the system. ERA is used for the leaching process of the system (circled in the scheme), MFA is used to model the intermediate flows (dotted line box in the scheme) and LCA is used to assess the environmental sustainability of the entire system (grey pentagon in the scheme).

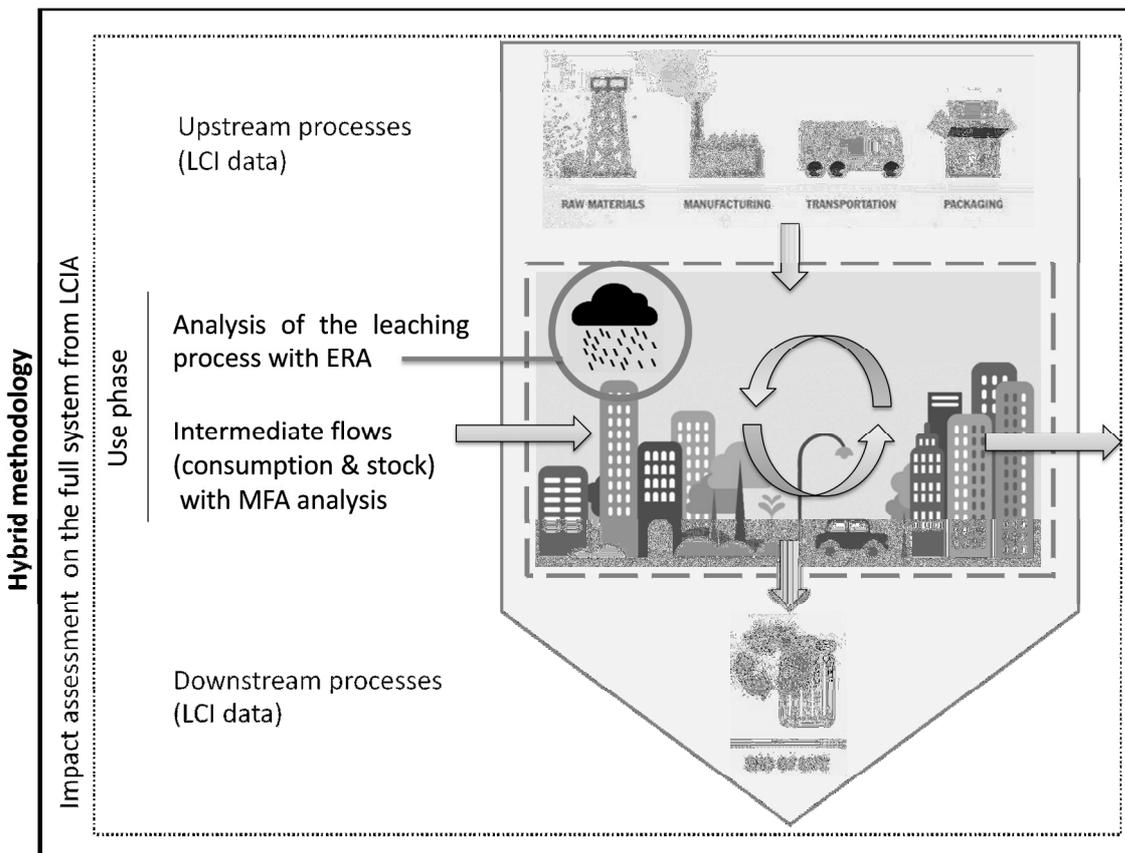


Figure 1. Hybrid approach scheme to model the urban anthropic activities and infrastructure

A case study: implementation example of the proposed hybrid methodology

This case study is a hypothetical neighborhood whose characteristics (density and morphology) are inspired by a French eco-district. It is assumed that the case study is located in the city center of a large French agglomeration and extends over a total area of 15 ha. This area has been designed with the concept of sustainable development in mind, especially in

terms of environmental quality. To this end, all buildings are low energy consumption buildings. Functional diversity, another guideline of sustainable urban development, is integrated into the neighborhood which includes collective housing -receiving 2000 residents- and spaces dedicated to different commercial activities like shops, service, sport, and culture. All buildings are considered to be new constructions. Buildings cover a total area of nearly 5 ha, therefore 10 ha are open spaces in the sense that they remain without buildings. Among these: green spaces cover 5 ha, roads cover 1.5 ha, and pedestrian mineral areas cover 3.5 ha.

A summary of the water flow network modeled with the MFA methodology is presented in figure 2. In this relative assessment of flows, the tap water and rain water inputs are divided between buildings, mineral spaces and green spaces. Those three main components of the district produce output water flows as evacuated wastewater, evaporation and soil infiltration (a). The network model of scenario (b) explicitly presents the recycling of water inputs in the systems including a stock for the rain water reuse. In this second scenario we consider that collective water tanks are disposed all over the buildings of the urban area and can serve as storage when the water is not used to clean the mineral spaces. The capacity of those tanks has been calculated with the rules of the NF P 16-005 standard.

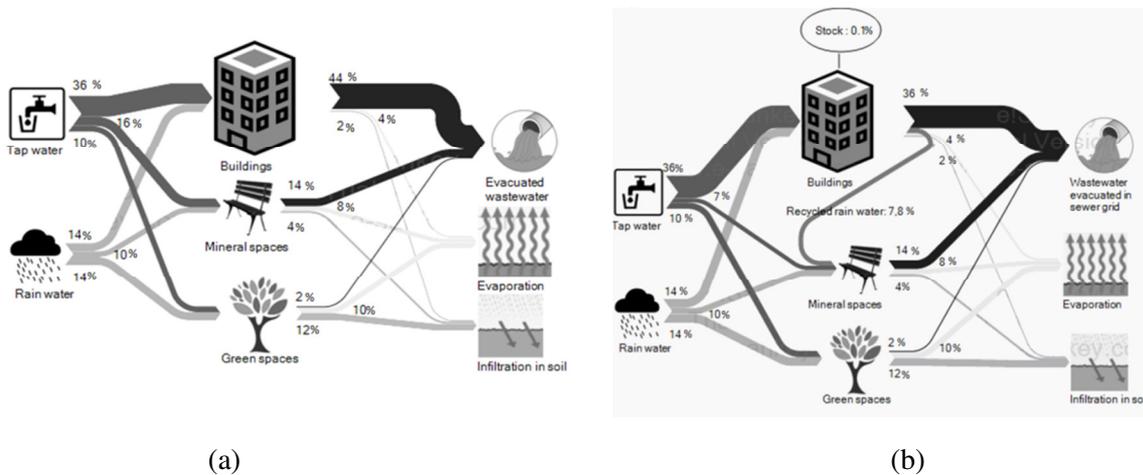


Figure 2. Network of water flows in the modeled system. Scenario (a) represents a traditional water management. Scenario (b) represents rain water reuse to clean the roads and pedestrian mineral areas.

As can be seen in the example of figure 2, using the MFA methodology to model the network of water flows in an urban area is a useful way to detect recycling and stock which are relevant information for sustainable management of the city. While those are relevant information, only looking at one type of environmental pressure (water use) might not be sufficient to choose the most environmentally performing scenario.

The use of the LCA methodology then becomes useful to compare the previous two scenarios. In this step of the hybrid environmental assessment of the hypothetical neighborhood we compare the differences between scenarios (a) and (b). This means that we assess different environmental impacts of tap water production and wastewater treatment for scenario (a) and compare it with a rain water recovering collective infrastructure for scenario (b). The results of this comparison are presented in figure 3 for different environmental impact categories.

The multi-criteria comparison of the two water management alternatives offers important information for decision makers who wish to choose the most environmentally sustainable solution. For example, a decision maker who promotes the importance of reducing water-use and waste management might choose the rain-water-reuse option (scenario b) while other (promoting the importance of energy consumption) would stay with the traditional method (scenario a). The benefit of making a multi-criteria impact assessment of the full life cycle of different scenarios for a section of the urban system is easy to understand when we look at the results of figure 3. And this is one proof that using the LCA methodology in our hybrid environmental assessment can be useful to avoid a development that might only shift the problem to another environmental impact category.

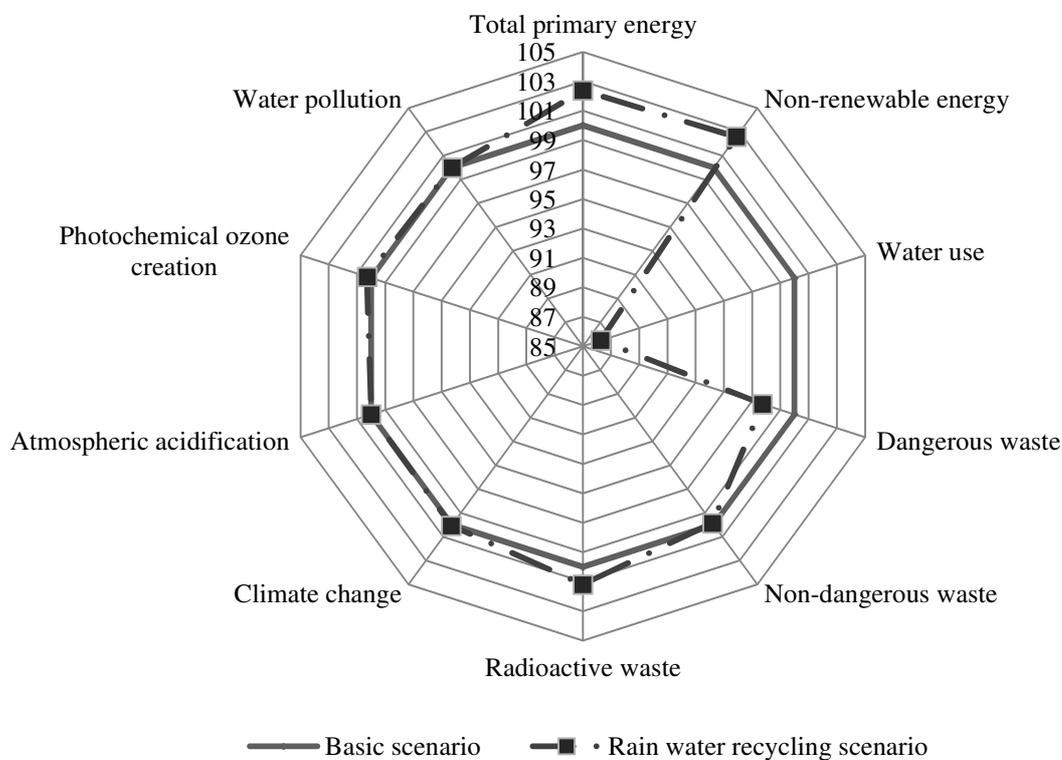


Figure 3. Scenarios comparison with multi-criteria environmental impacts assessment for the UM system

Today, the implementation of impacts assessment in LCA studies does not efficiently consider local effects of emissions. This shortcoming was minimized by the use of the ERA methodology for the leaching process (emissions of substances from built area to water and soil) that is known to have important effects at a local scale [10]. To make this assessment we used one of the approaches presented in the previous studies [9,10]. The leaching process of rain on the construction products of the neighborhood buildings is based on the work of Lupsea [10] for wood and Schiopu *et al.* [11] for concrete. For the assessment of these impacts we used the SimaPro LCA software with the USEtoxTM (v1.01) method. USEtoxTM is considered as the best suggested method up to now for the evaluation of ecotoxicity impact of released substances to the environment [12]. The calculation of damage to eco-system quality is based on the indicator Potentially Disappeared Fraction (PDF) of species. For the leaching



process modeled in this study we found a value of 1166 PDF·m²·year, i.e. 2.3%. These ecotoxicity impacts would be neglected if the leaching process would not be taken into account in the assessment. The example given here shows one of the benefits of integrating the ERA principles into environmental assessment at urban scale.

Discussion

The presented hybrid methodology combines many benefits of commonly used environmental assessment methodologies like MFA, LCA and ERA. The hybrid methodology benefits from the MFA are its capacity to identify stocks and material loops in modeled systems. The LCA then enables the multi-criteria assessment and the ERA offers the possibility of assessing local impacts for specific anthropic process of urban activities and its infrastructure.

The main challenges with this hybrid methodology are the amount and the heterogeneity of the data that is needed to model systems. This is mostly related to the bottom-up approach of system modeling that is used for any of the methodologies that are used to create the hybrid methodology.

Conclusion

The hybrid methodology build in this work combines the strengths of three environmental assessment methodologies: the UM / MFA - Urban Metabolism / Mass Flow Analysis (for network modeling), the LCA - Life Cycle Assessment (for multi-criteria impacts and life cycle perspective), and the ERA - Environmental Risks Assessment (for impact assessment at the local scale). The hybrid methodology is based on modular and systemic principles. The modularity allows for detailed assessment of each system compartment and to use data issued from different existing specific tools (e.g. building scale data issued from building assessment tools, environmental assessment data for infrastructure, etc.). The systemic principle allows taking into account the interactions between different system compartments in order to complete the assessment of the global system environmental performance. The description of benefits and challenges for this hybrid methodology were given through its implementation for specific examples. The findings of this study offer insights on the importance of combining the benefits of different methods for the assessment of anthropic systems in urban areas.

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A contextual and spatial approach towards resource cycles

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Abstract

Multiple system-based concepts exist to analyse and manage urban throughput of resource flows, examples are Urban Metabolism, Industrial Ecology and Energy Potential Mapping. Common threads in these propositions are fundamental principles valid in nature, notably homeostasis and thermodynamics. Those and likeminded concepts are valuable links in the shift from a reductionist towards a holistic notion of the built environment. However, practical implementations of system-based interventions appear to lag behind. This ‘system failure’ can be allocated to the inherent complex nature of associated challenges and threats. This paper focuses on attributes of sustainable urban development that are as yet insufficiently understood, revolving around contextuality and spatiality. A case study in the metropolitan region of Amsterdam Airport Schiphol is introduced to explore regional synergies, in particular with regard to two hotspot zones. It is urged that for sustainable resource management, regional systems-integration is a critical factor. Unravelling supply & demand patterns in the designated area unveiled multiple potentials for circular resource flows and mutual benefits for networked actors.

Key words: sustainable development, systems integration, resource efficiency, circularity, urban mining, energy potential mapping

Introduction

Within the current European governmental and scientific agendas, the aim for sustainable urban development is increasingly approached in an integrated manner [1]. This means that critical interrelated components comprising urban systems should all be taken into account when diagnosing the performance of that system on the one hand, and developing improved pathways on the other. Furthermore, special attention is addressed at essential resources that drive urban processes, and – more specifically – the way to shift from a predominantly linear approach to a circular one in order to increase resource efficiency.

For the analysis and management regarding urban throughput of resource flows such as energy, materials, water and food, multiple system-based concepts exist. Examples are Urban Metabolism, Industrial Ecology and Energy Potential Mapping. Common threads in these and likeminded propositions are fundamental principles valid in nature, notably homeostasis and thermodynamic laws. These principles are aimed at the creation of synergies between components in a system and – ultimately – sustainable societies. Abovementioned concepts are valuable links in the shift from a reductionist towards a holistic notion of the built

environment. However, it can be observed that practical implementation of interventions that derive from such system-based concepts lags behind. This system failure can be allocated to the inherent complex nature of associated challenges and threats, with regard to e.g. technical limitations, sectoral concerns, regulatory framework and knowledge gaps [e.g. 2, 3]. Vernay [2013] argues that the largely technocratic nature of developed ideas within the existing concepts leads to an implementation gap, because there is “a poor understanding of *how* these ideas can actually come into being”.

The rationale behind this paper relates to a better alignment of technical interventions on the one hand and regional characteristics on the other in achieving integrated sustainable urban development. The paper stems from studies of resource flows and their infrastructures in urban areas, accentuating two attributes of sustainability that are as yet insufficiently understood: context and space. The former refers to the notion that understanding – and intervening in – aspects of a system (e.g. energy use in buildings, neighbourhoods or regions), aimed at potential synergies between functions, can only occur in conjunction with the regional characteristics, such as geography, morphology, production/consumption patterns, and planning strategies. The latter refers to the notion that spatial arrangements associated with shifts in resource management have a huge impact on the lay-out and quality of our living environments.

This paper is structured around the following main research question:

- *Taking into account contextual and spatial characteristics, which potentials can be identified that facilitate the shift to sustainable urban systems based on circular resource flows and regional integration?*

In the following section, first a methodology is presented in which empirical and theoretical data of selected resource flows are inventoried, interpreted and synthesized into flow maps and potential maps. This methodology is part of the Better Airport Regions project [4], with the metropolitan region of Amsterdam Airport Schiphol as its case study area. Next, the results of the flow analyses in the case study area are briefly addressed, and the results of the potential maps in more detail. Finally, the findings are discussed against the backdrop of sustainable transitions in urban (airport) regions from the perspective of integrated systems.

Better Airport Regions (BAR), case study Amsterdam Airport Schiphol

The methodology introduced in this paper is part of an integrated endeavour, addressing sustainable development of metropolitan airport regions. BAR comprises multiple interwoven modules that focus on technical, spatial characteristics of resource flows in the airport region on the one hand and the related organisational and institutional context on the other [5].

Figure 1 visualises the methodical steps for analysing and mapping resource flows relevant to the performed case study of Amsterdam Airport Schiphol (from here on: Schiphol).¹ We

¹ As performed in Module 1 (Essential Flows) of the BAR project

applied an iterative method, in line with the dynamics around acquiring knowledge necessary for advancing in the research. After a literature study, the context of the study was laid out, area boundaries were set, and resource flows and indicators determined. The inventory stage comprised: i) system analysis, ii) initial flow charts, and iii) data collection. The quality of the findings was assessed and monitored to see whether they were in line with the goal and scope or adjustments were required. Next, the generated data were synthesized into flow maps. Through interviews and workshops with researchers as well as private and public stakeholders the flow maps were validated and interpreted. Subsequently, several geographic and thematic areas emerged with specific potential. These so called *hotspot zones* dictated a tailor-made analysis, of which the results are precursors for generic lessons, potentially applicable in other regions as well. Moreover, the generated data and – flow and potential – maps contributed to an indication of ways in which the various flows are or could be interconnected.

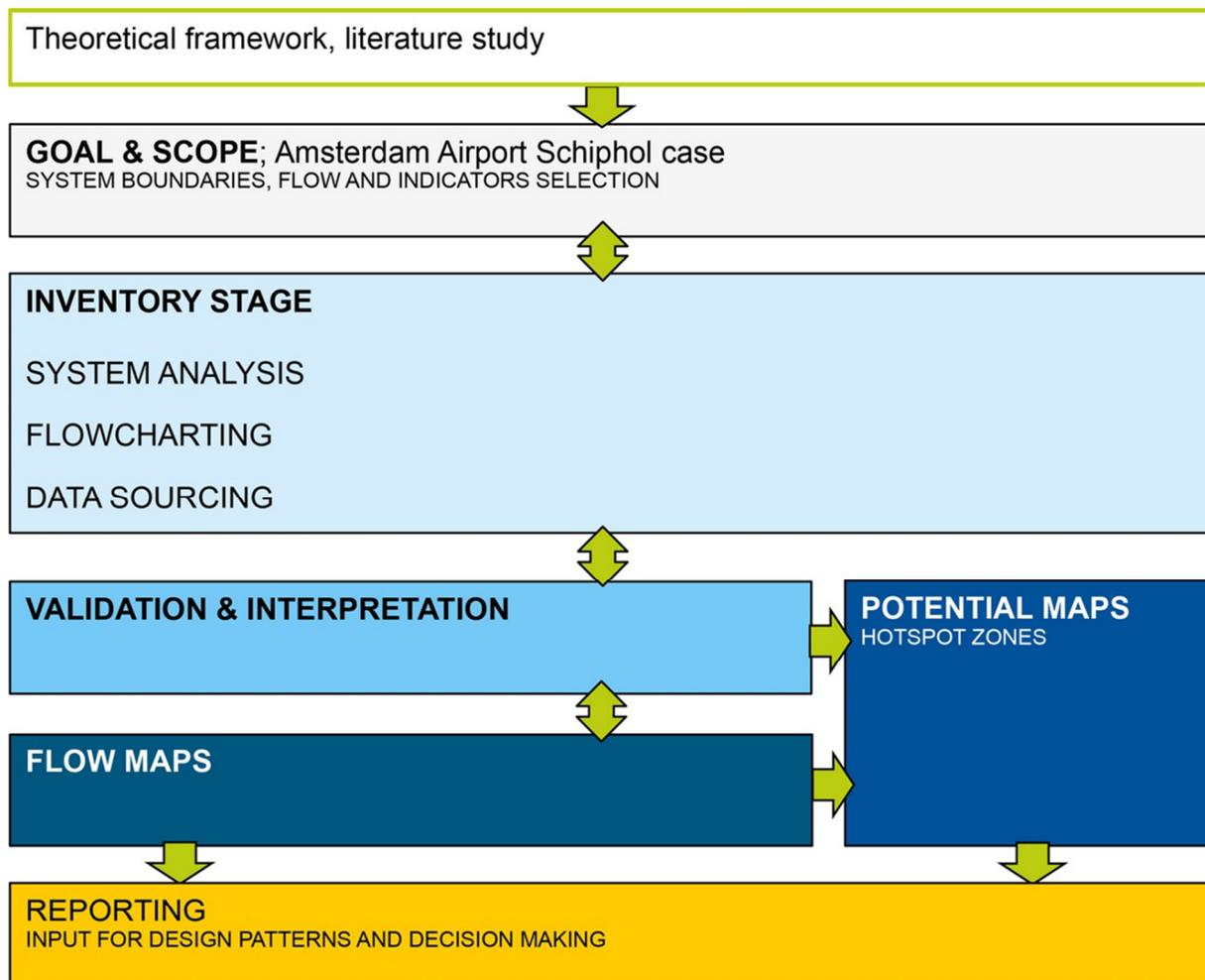


Figure 1: Better Airport Regions project research methodology (module 1: Essential flows)

Schiphol with its surrounding municipalities formed the geographical system boundaries central to this study, see Figure 2. Schiphol was defined as the 1st level system, subject to a

detailed flow analysis. The 2nd level area follows the borders of the municipalities that directly surround Schiphol. Flows in the latter area were explored in broad outline.

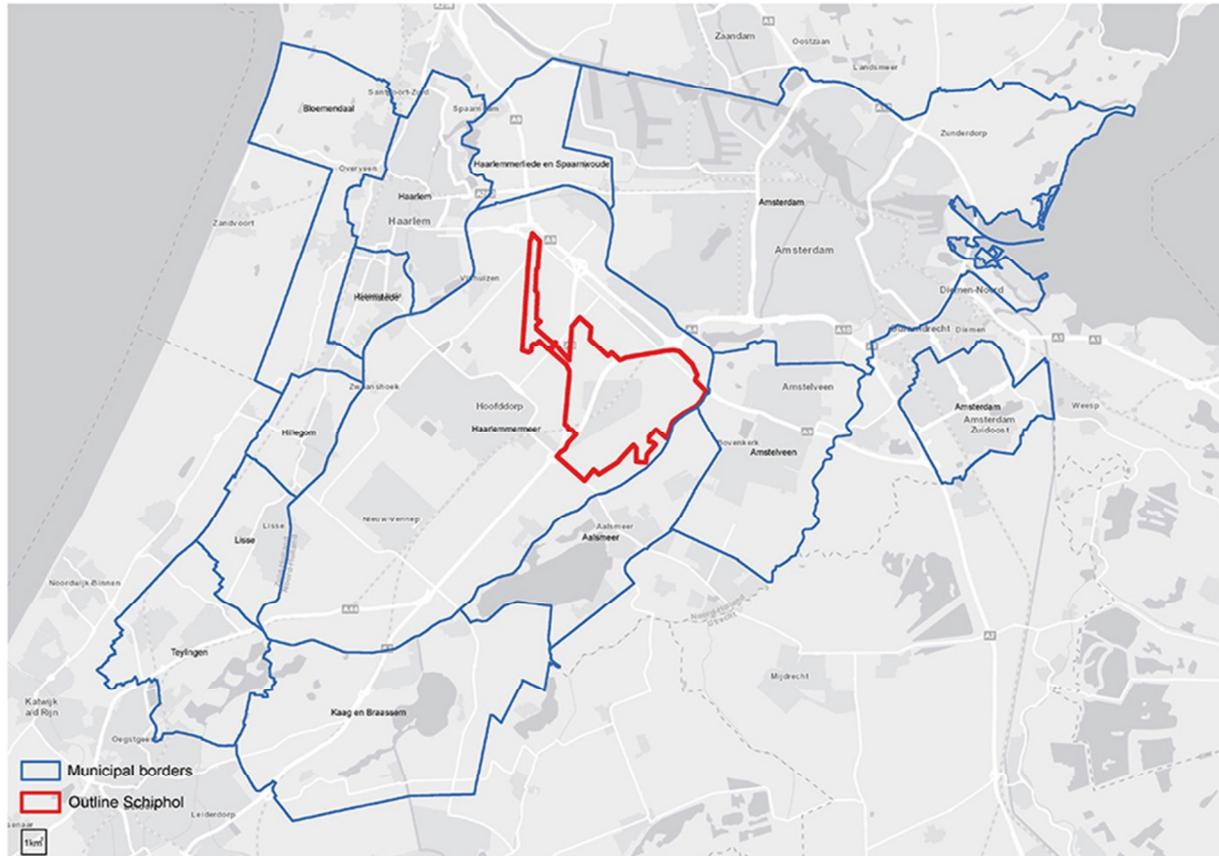


Figure 2: System boundaries of the Schiphol airport region as applied in the BAR project

Selected flows & throughput of Amsterdam Airport Schiphol

The people ‘inhabiting’ Schiphol can be divided in three categories: passengers, workforce and visitors. Approximately 50 million passengers passed through Schiphol in 2011 [6]. The workforce at Schiphol contains around 60,000 employees, working for 500 companies. The category of visitors adds up to 13 million visitors in total. Furthermore, about 1.5 million ton of freight passed through the airport in 2011 [7]. All these people and processes make use of resources. The resource flow selection stage led to a focus on: energy (electricity, gas and transport fuels), materials (plastic packaging materials), food (divided in six food groups: carbohydrates, vegetables, fruits & nuts, meat products, fish products, and dairy products), water (drinking water and wastewater) and waste. Table 1 is an overview of the volumes through Schiphol concerning these flows.

Table 1: Schiphol throughput of selected flows in 2011

PEOPLE	Passengers	Workforce	Visitors			
	50.000.000	60.000	13.000.000			
ENERGY	Electricity TJ	Gas TJ	Fuels TJ			
	1.180	975	11.900			
WATER	Drinking Water m ³	Wastewater pollution units				
	1.220.000	45.000				
MATERIALS	Plastics: PET tonne	Plastics: Unspecified tonne				
	388	434				
FOOD	Carbohydrates tonne	Vegetables tonne	Fruits/nuts tonne	Meat products tonne	Fish products tonne	Dairy products tonne
	11.500	5.930	3.290	5.270	1.650	5.270
WASTE	Total waste tonne					
	13.900					

Flow Potentials: Hotspot zone studies

Characteristics and associations that emerged from the initial flow analysis were listed in order to identify zones with particular interest to explore in greater detail. During internal workshops, researchers with various backgrounds – notably engineering, industrial ecology and urban planning & design – further discussed these characteristics and developed a shortlist of six *hotspot zones*, visualised in Figure 3. Through interviews and workshop sessions with public and private stakeholders these hotspot zones further evolved.

Determination of the shortlist was done by five primary criteria:

- Presence of specific flow potentials; for example large volumes of excess heat
- Spatial relevance; the area's morphology and its spatial potential for interventions in resource management (production, storage, infrastructure)
- Strategic relevance; the area's identity regarding the organisational and regulatory status
- Current or planned developments
- Spatial and thematic dispersion

Each hotspot zone revolves around one or more coinciding main theme rooted in, but not exclusive to, that specific context; generic lessons can be drawn through the specific examples. In the next section two of six hotspot zones are further discussed, namely: nr 1. BESt Energy Exchange, and nr 3. Urban Mining of Airports (UMA) – plastics².

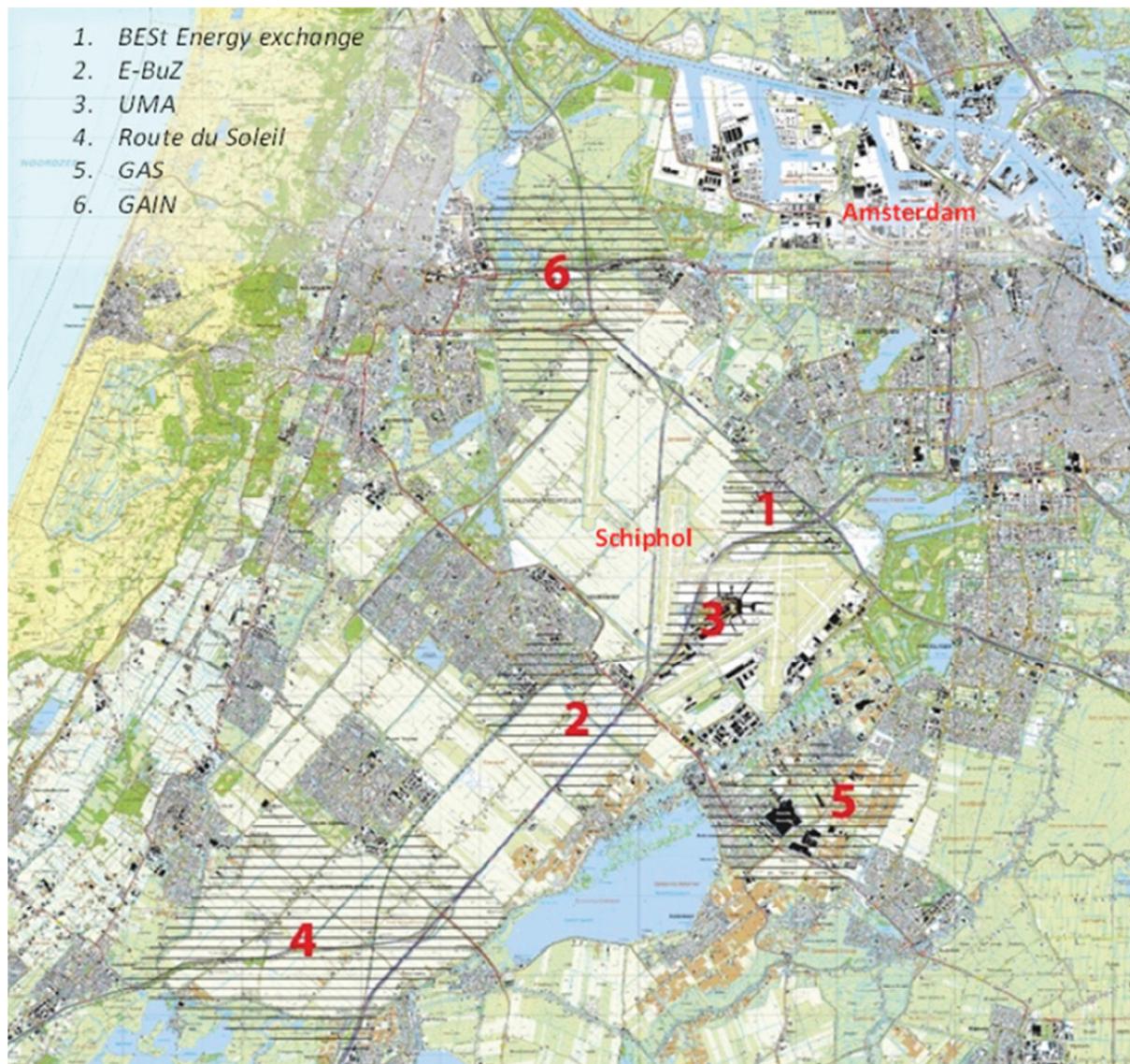


Figure 3: Six hotspot zones in the Schiphol airport region

Hotspot zone BESt – A smart grid for heat and cold exchange

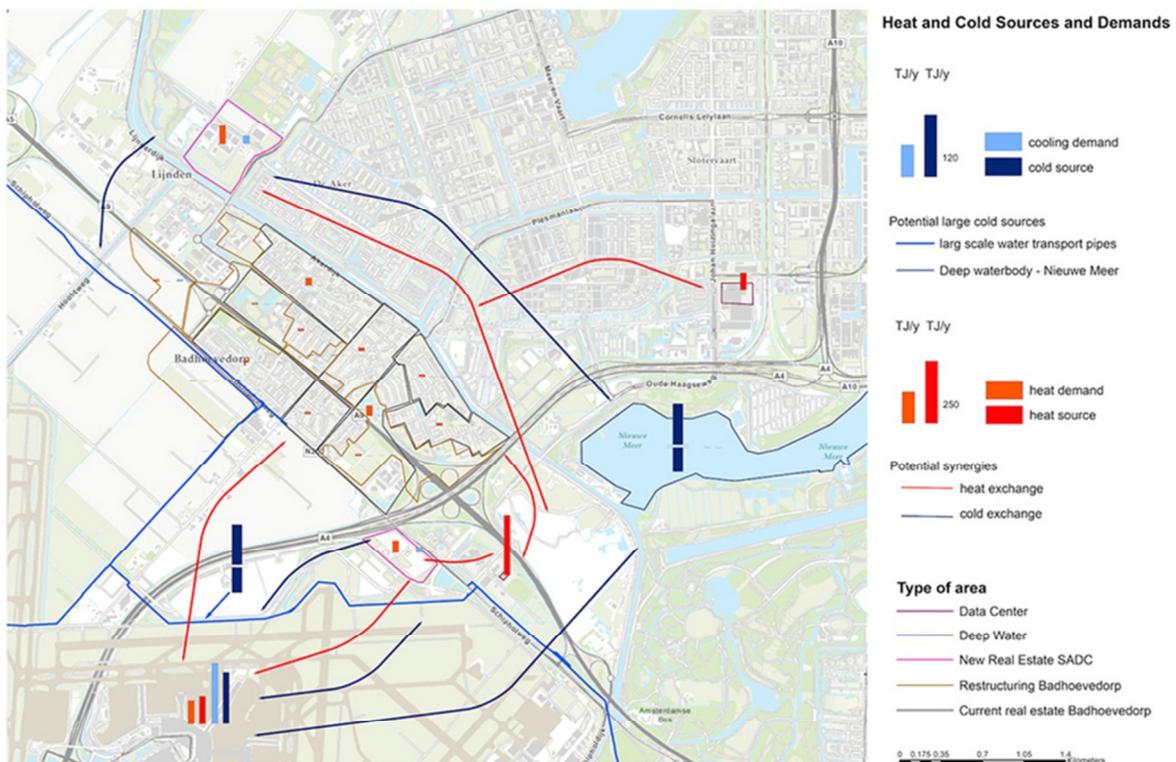
In Badhoevedorp, just North of Schiphol, a variety of real estate and restructuring plans is under development or foreseen for the near future. Each plan comes with a particular energy demand, which could in theory be covered by collective thermal energy systems centred on a low temperature heating/high temperature cooling net. Excess heat from Schiphol could be part of such a thermal energy net. On the other hand Schiphol has a large and energy intensive

² A second research in this hotspot zone was allocated to the recovery of nutrients in wastewater

cooling demand, for example relating the heat production associated with daily fluxes of passengers in terminals. Water transport pipes that run under the north of Schiphol could provide a significant and constant source of cooling, albeit with temperatures that vary over a year.³ Furthermore, business zone Elzenhof, neighbouring Schiphol and Badhoevedorp, accommodates a large datacentre. This datacentre produces a constant flow of waste heat and explores options to render this waste heat useful. Lastly, in Amsterdam, a city-cooling grid is currently under development, using deep lakes – that came into existence through sand extraction – as point sources. One of these lakes, namely the Nieuwe Meer, borders the Badhoevedorp/Elzenhof/Schiphol triangle (BEST) in the northeast.

Built on the abovementioned facts, a distribution and storage net for heat and cold in the BES triangle presents an opportunity to serve mutual interests of suppliers and customers. The associated technology and infrastructure is relatively straightforward, and both supply and demand capacities are promising. Moreover, the thermal quality of the transport medium can be sustained over reasonably long distances, in that respect bridging the distances in the BES triangle is not an obstacle. The map of figure 4 displays heat and cold sources and sinks, with an indication of the capacities (in TJ/year), and potential synergies in the BES triangle. New real estate of Schiphol Area Development Company (SADC) outside of the airport boundaries is also indicated with its estimated heat and cold demands. Furthermore, the underground water supply transport pipes are visualised on the map.

Hotspot Zone: BEST - Energy exchange



³ The 'Rivier- Duinwaterleiding' (River-Dune water supply)



Figure 4: Energy exchange potential in the Badhoevedorp/Elzenhof/Schiphol triangle

The BEST energy-exchange concept brings energy supply and demand patterns of local components together. Some characteristics are predominantly generic, such as the presence of water-bodies and occurrence of heat losses (excess heat) from industrial processes. Other characteristics are more specific, in particular with regard to the subterranean water supply pipes. There is a variety of temperatures associated with the supply and the demand side; roughly from 5°C (e.g. lake water in winter) to 40°C (e.g. datacentres). A smart distribution grid is envisioned, in which the required thermal qualities are available at the right place at the right time, following a *cascade* of functional applications, including storage capacity for load balancing. Supplementing such a grid with functions that utilize leftover energy at the end of the cascade would enhance its effectiveness. An opportunity in this respect is making a link with algae cultivation at Schiphol. This relates to an earlier experiment at the airport concerning the purification of glycol-containing de-icing water with algae. One of the main reasons for the failure of this experiment was that glycol containing feedstock is primarily available in winter, when temperatures are far from optimal for algae growth; this discrepancy could be compensated by utilizing low temperature waste heat as part of the proposed heat/cold exchange and storage network. Algae could subsequently play a role in multiple applications, providing feedstock for food, feed, pharmaceuticals, fine and/or bulk chemicals.

Hotspot zone UMA – Urban Mining in Airport regions; plastics

On-going efforts at Schiphol to valorise valuable waste fractions lead to increasing recycling rates associated with solid waste. Plastics, mainly from packaging, are to some extent separately collected and transported to recycling facilities. With 100 tonnes per year, PET is currently the primary polymer in this context, but there is good recycling potential for other polymers as well. With regard to waste from aircraft, recycling is virtually absent; in accordance with safety regulations, much of the total aircraft waste is incinerated within 24 hours. The plastic fraction of this waste flow – 720 tonnes annually of which 40% PET (288 ton) and 60% unspecified (432 ton) – could easily be fed into common practice recycle routes. Recycling generally leads to a better environmental score and conserves more energy than is generated by incineration [e.g. 8, 9].⁴ Given the specific conditions of the waste collection in aircraft, i.e. hardly accommodating for waste separation at the source, post separation seems the most appropriate step towards recycling – and the next best option after *reducing* that waste flow. With regard to plastics in municipal solid waste (MSW), on average 25 kg is produced per capita per year, the majority of which disappears in incinerators: 15-20 kg. In the municipalities surrounding Schiphol this implies a production of 20-27 kton plastics in domestic waste streams for incineration annually. However, the lion's share, consisting of the polymers PET, PP, PE (HDPE and LDPE), PVC, and PS can be recycled following common recycling routes (see also Table 2).

⁴ Incineration with energy recovery – electricity and heat – leads to approx. 500 GJ of electricity and 1,900 GJ of heat + losses. Caloric value of this waste is approximately 10 GJ/tonne and the efficiency is 21%.

Figure 5 displays the division in percentages per polymer type in the solid waste flows of Schiphol and its surrounding municipalities.

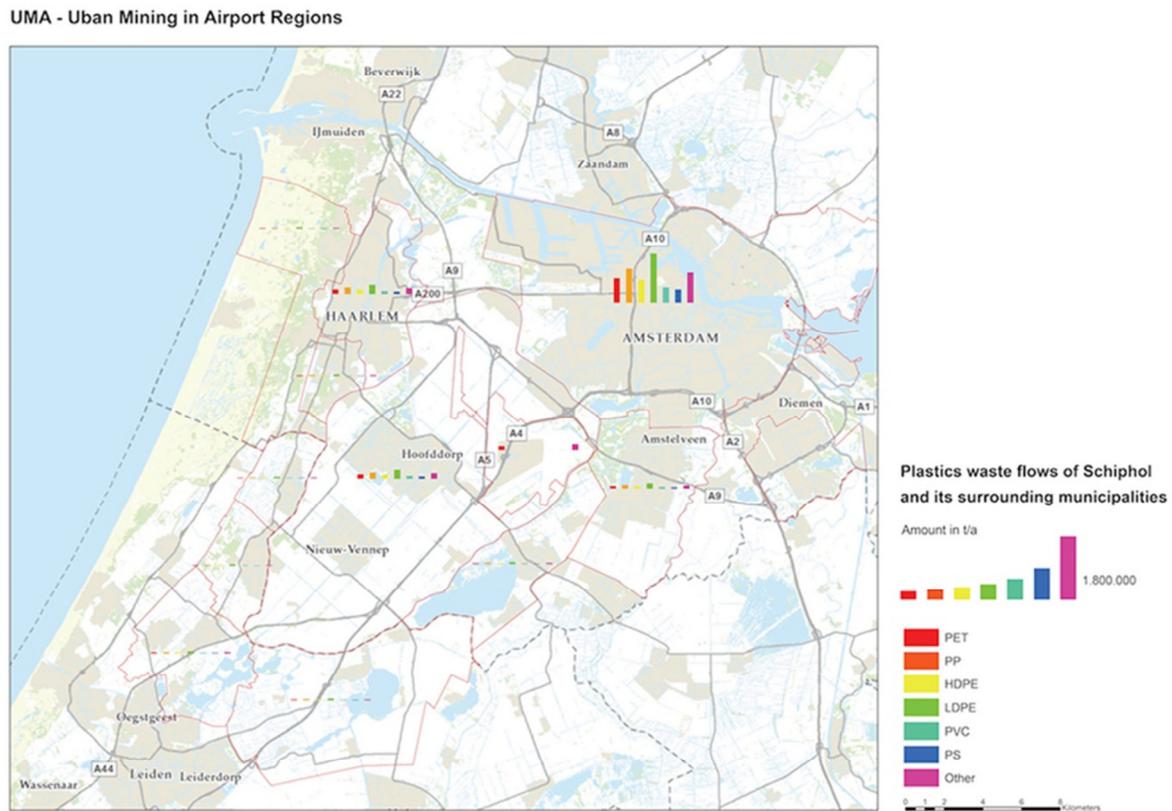


Figure 5: Plastic packaging throughput of Schiphol and its surrounding municipalities in 2011

Expanding the plastic recycling efforts in the airport region centres on potential economies of scale and the shift from waste related costs to added value through recycling. Table 2 lists the main polymers used for packaging, whilst also being indicative for the main products or product categories that enter the airport. Furthermore, the table lists the packaging applications, identification code for recycling purposes, and recycling routes. Because of the close relation with food – another resource flow included in the BAR research – other plastic products associated with airports, such as disposable containers, cutlery and trays, are also included in the table.

The polymers could either be recycled into the same type of product; closed loop recycling, or into another; open loop recycling. Given the fact that many of the currently applied recycling steps imply a diminished material quality, compared to that of the polymer materials used in the primary stage, *downcycling* is usually more appropriate as a term.⁵

⁵ In their book 'Remaking the way we make things' [2002] Braungart and McDonough introduce their Cradle to Cradle approach, which distinguishes different kinds of recycling. In their reading, down-cycling implies the loss of intrinsic quality, whereas up-cycling implies added quality to the recycled material or product.

Regional collaboration relating collection, separation and storage may offer the economies of scale required for viable business cases based on circular resource flows. A remanufacturing – or polymer recovery – facility could well be implemented in one of the industrial/business zones in the region.

Table 2: Polymers for packaging + recycling routes

Polymer	Identification code	Examples of (packaging) application	Examples of recycled content applications
Polyethylene terephthalate (PET, PETE)		Plastic bottles for soft drinks, water, juice, sports drinks, beer, mouthwash, catsup and salad dressing; food jars; food trays	Fiber for carpet; fleece jackets; comforter fill; carrier bags; containers for food, beverages (bottles), and non-food items; film and sheet; strapping.
High-density polyethylene (HDPE)		Bottles for milk, water, juice, cosmetics, shampoo, dish and laundry detergents, and household cleaners; grocery bags, cereal box liners; reusable shipping containers.	Bottles for non-food items; plastic lumber for outdoor decking, fencing and picnic tables; piping; floor tiles; buckets; crates; flower pots; garden edging; film and sheet; recycling bins.
Polyvinyl chloride (PVC)		Rigid packaging applications, such as blister packaging for non-food items; flexible packaging, such as bags for bedding; cling films for non-food use.	Piping; decking; fencing; paneling; gutters; carpet backing; floor tiles and mats; resilient flooring, mud flaps; trays; electrical boxes; cables; traffic cones; garden hose; packaging; film and sheet; binders
Low-density polyethylene (LDPE)		Bags; squeezable bottles; cling films; flexible container lids; coatings for paper milk cartons; hot and cold beverage cups.	Shipping envelopes; garbage can liners; floor tile; paneling; furniture; film and sheet; compost bins; trashcans; landscape timber; outdoor lumber.
Polypropylene (PP)		Reusable microwaveable ware; kitchenware; yogurt containers; margarine tubs; microwaveable disposable take-away containers; disposable cups; plates.	Automobile applications, such as battery cases; signal lights; battery cables; brooms and brushes; ice scrapers; oil funnels; bicycle racks; garden rakes; storage bins; shipping pallets; sheeting; trays.
Polystyrene (PS)		Egg cartons; protective and insulating packaging; disposable cups, plates, trays and cutlery; disposable take-away containers;	Thermal insulation; thermometers; light switch plates; vents; trays; rulers; license plate frames; cameras or video cassette casings; foamed foodservice applications; plastic mouldings; expandable polystyrene (EPS) foam protective packaging.
Other (often polycarbonate: PC or Acrylonitril-butadien-styreen: ABS)		Beverage bottles; baby milk bottles; custom packaging; housing for electronics and compact discs	Bottles and plastic lumber applications.

main source: American Chemistry Council

Discussion and Conclusions

The described approach to analyse essential resource flows in airport regions has led to a better comprehension of current flow management at the airport. In the presented methodology qualitative and quantitative flow analyses on the one hand and local characteristics on the other are coupled, whilst revealing synergetic potential between resource flow considerations and spatial planning directions. These synergies derive from the case study region, containing specific potential for local projects as well as generic lessons applicable to other airport regions. Contextualization of the detected flow potential is facilitated by zooming into designated hotspot zones The five main criteria to determine these zones will arguably lead to a more integrated, region-specific selection procedure. Studying the hotspot zones reveals patterns in which challenges, context, potential solutions and spatial implications are coupled. The methodology thus helps to better understand the fabric that complex challenges, such as sustainable development, are made of. Two – interrelated –



aspects in particular have come to the surface as critical factors that determine the value of the proposed methodology and its results: complex system dynamics and data quality. Below, those aspects are further discussed.

Complex system dynamics

Airports, being complex systems in their own right, interact with their direct surroundings in complex and multifaceted ways. Reciprocal relationships with those surroundings imply surplus value rather than nuisance in the form of noise, pollution and traffic congestion; associations that currently seem to prevail. This reciprocal relationship relates to new paradigms in dealing with essential resources. Reciprocity not only implies a symbiotic relationship but also a degree of mutual obligation that comes with it. These are properties of systems thinking and underline the non-linearity in complex systems. The proposed methodology results in identified potentials that are largely of a technical nature. But technology is often not the limiting factor with regard to breakthroughs of sustainable innovations [Vernay 2013]. In that respect, the methodology contains a paradox: a *reductionist* approach to ultimately understand a *holistic* system. However, this methodology is part of an integrated effort to understand complex systems, whilst yielding *sub*-results as input for design patterns. Those patterns are subsequently coupled with spatial design, planning and governance modules. In this way the opportunities detected in the case study area of the Schiphol airport region obtain systems based value.

Data quality

During the research, we have strived for the highest data quality possible within the restrictions dealt with. However, due to the complexity and size of the study area, as well as the amount of data owners and stakeholders, a certain asymmetry in data has to be taken into account. In those cases the emphasis is more on qualitative than on quantitative results. Despite the cooperation of several key players, data –if existent at all– are in many cases not readily available. Lack of transparency is an issue here in two ways: firstly, actors may not want to – or be allowed to – share certain information. Secondly, actors may not share the piece of information that is valuable for us, and/or they may not be aware what the significance of specific information is. In the first case it is clear that confidentiality renders data out of reach. The latter case, however, is more ambiguous and seems closely connected with individual sectorial concerns, as referred to in the introduction. During the research we have explicitly operated from a systems approach towards sustainability; data are assembled to anticipate non-sectorial solutions. It is not self-evident that this approach coincides with the interests of individual actors. However, outlines of specific projects become discernible in the hotspot zones, which may appeal to individual actors as much as the society. This appeal is thought to create the required incentives for individual actors to take next steps in generating and sharing data.



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INDI: a neighbourhood rating tool with a whole life value analysis for buildings

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Abstract: *The European directive on energy performance in buildings (EPBD) will bring in 2020 new national thermal regulation for nearly zero energy buildings (NZEBS). The first generation of nearly zero energy buildings has raised important questions on costs (their building construction cost itself and their maintenance and exploitation costs) but also on health, quality in use... (as shown already by the German DGNB). To try to answer to each of these questions, we worked out a whole life value analysis of these NZEBs and we added this decision aid tool in our econeighbourhood referential INDI: the INDI-2015 vintage.*

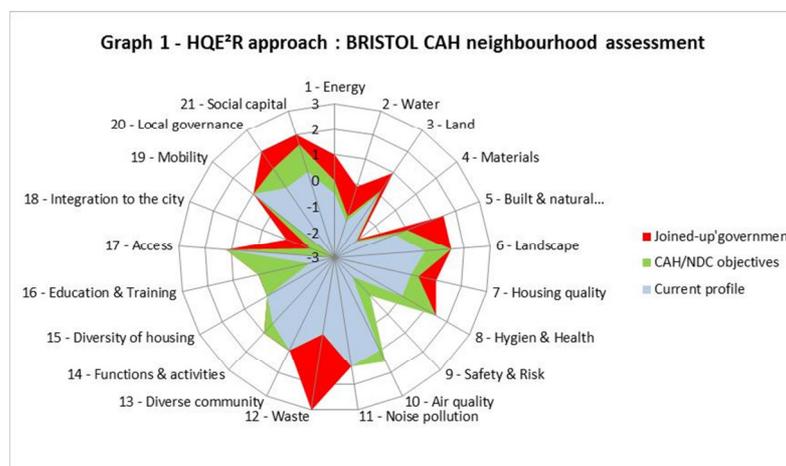
Key words: *econeighbourhood decision aid tool, NZEBs whole life value, from life cycle cost (LCC) to whole life value*

2001 – 2004: the HQE²R approach and its tools (ISDIS, INDI...)

The HQE²R European Project (2001-2004) on sustainable renovation of neighbourhoods (cf. www.suden.org) allowed us to work out the HQE²R approach and its tools to assess a neighbourhood renewal project with indicators according to the following structure:

- **5 global sustainable development issues** giving the standard framework (ISDIS);
- **A shared sustainable development diagnosis** of the neighbourhood including also a building environment analysis with 74 **indicators** for answering to 21 objectives (for each of the 21 thematic areas);
- Local urban renewal **objectives** (dealing with buildings and building environment) showing the effort needed for each sustainable development indicator.

This HQE²R approach and the first version of INDI can be illustrated with the graph 1 showing the initial shared diagnosis of the CAH neighbourhood in Bristol (in blue), the assessment of the renewal programme showing the improvement for each of the 21 objectives (in green) and the improvements which should be possible by using all the financial subsidies or helps offered by local or national authorities (in red).



Source: HQE²R, 2004

2010 – 2012: second step for the INDI econeighbourhood referential: the INDI - 2012 vintage
 In 2010 INDI has been adapted to any neighbourhood project including sustainable development (econeighbourhood or sustainable neighbourhood project): new urban areas, urban renewal or both of them, with a real social and environmental dimension.

The INDI referential has been completely modified in order to become INDI–2012, a decision aid tool for land planners and local decisioners. Urban planners and consulting offices working for building owners have used this completely new version of INDI, which is now structured on:

- **4 stakes** going from global to local and to governance purpose;
- **235 questions** for economic, social and environmental issues. For each of them, threshold and target values are suggested in order to assess the neighbourhood project as regarding the benchmarks considered as best practices. These values are not norms or prescriptions but help to know what should be done and to better understand and imagine what can be done according to the local context (human and financial resources, social problematics, geographic context and so on...).
- These 235 questions are grouped in a set of **127 composite indicators**, themselves distributed in the **20 thematic areas** of the approach.

INDI–2012 can be used for each type of neighbourhood project (urban renewal or new areas) and allows, as in its initial version (illustrated by the diagnosis and assessment done for the Bristol neighbourhood in the previous schema), the comparison between several land planning scenarios for the neighbourhood. But INDI–2012 can also be used as a decision aid tool for designing the project, within a relatively exhaustive land planning approach allowing improving strategies as it has been done in 2012 for example for the La Courrouze project in Rennes (Britany, France) (cf. graph 2 and table 1).



Source : La Calade for Territoires & Développement, 2012

Table 1 – Improvement actions issued from a INDI analysis

Improvement actions for the La Courrouze neighbourhood	Level of priority
To define more ambitious performance objectives for construction	+++
To anticipate the possible reduction of the car in the city	+
To improve the quality of the buildings sites	++
To experiment new transport systems	++
To favour e-working in the neighbourhood	+
To develop a large steering committee for the neighbourhood	+
To improve the taking into account of the climatic change in the projects	++
To develop the renewable energy sources	+++
To be concerned by the household electricity consumption	+
To favour the complementarity between the economic activities	+
To use local and renewable materials in the construction	+
To reinforce the prescriptions for construction	++
To promote the business for small and medium enterprises	+
To strengthen social inclusion in construction and operation	+
To encourage the participation of inhabitants for public spaces lay-out.	+
To facilitate the co-production of building by inhabitants association	+

Source : *La Calade for Territoires & Développement, 2012*

INDI-2012, as all referentials, is **a thematic approach** containing a lot of questions and indicators inside a lot of thematic areas and the main difficulty is to have a cross-cutting approach.

But **a cross-cutting approach** is absolutely necessary. The energy thematic area for example has impacts in each of the sustainable development pillars: environmental impacts (energy consumption, greenhouse effect gas emissions) but also economic impacts (energy expenses, financial need for investment, creation of new local economic sectors), social impacts (employment, reduction of energy poverty) and at least governance impacts (the dependence of local authorities on the great energy and building enterprises, users behaviours). We can see the same interdependence for most of the thematic areas, such as economic development, local governance, fight against exclusion... This is the reason why **INDI-2012 has also cross-cutting modules** (energy, landscape, open space...) and, among them, one dealing with buildings (retrofitting and construction works).

2014 – 2015: a whole life value analysis for the INDI - 2015 vintage

Specific building analyses have shown us there was a need for going further, for an additional cross-cutting approach between all the parameters of a building analysis: a whole life value analysis.

Life cycle costing (LCC) is an approach which intends to integrate all the costs and benefits (incomes) of a building from the first beginning of the design phase to its demolition (end of life) including of course the construction and the using (exploitation) phases.

Several issues are very important during the designing and the retrofitting phases of a building:

- There is a need for a **direct life cycle cost analysis** for dealing with all the costs during the building life: construction, exploitation and maintenance costs.
- The impact of a building construction project has to be measured in terms of embodied energy and greenhouse effect gas (GEG) emissions. The energy prices' evolution, as well as the fight against the climatic change, have to be taken into account too.



- Buildings environmental quality contains also many issues, as it can be seen with the French HQE approach or with BREEAM for example.
- Failure with the building completion time has usually an important cost impact, for the building owner as well as for the future users of the building. The reason of such a failure can be due to the timing process but also to administrative or commercial actions due to the more and more complex procedures (with more and more legal constraints).
- It is more and more difficult to be conform with the initial required specifications because of budgetary restrictions: very often the ambitious objectives of the beginning are forgotten one by one because of budget reasons (because the budget has not been well estimated, cost has have been underevaluated, or because the financial engineering is not efficient (because not paid enough or... not required).
- Buildings can generate numerous *health and social impacts* because of the products and/or equipments used and because of the quality of life and building quality in use inside the building. These two types of impact are more and more important when reducing energy consumption and when using more and more sophisticated equipments for air change (ventilation).

Quality in use has to be considered according to its two aspects: for the owner or the manager on the one hand and for users on the other hand. Users speak about comfort and low exploitation costs and, if the manager or the building owner wants low costs too as regarding maintenance and retrofitting, he also looks for the adaptation capacity of the building (for new uses).

The whole life value analysis goes further than the HQE or BREEAM approaches; it deals also with economic, heathy and ecological issues. So the usual approaches and referentials with indicators (HQE, BREEAM, INDI or INDI-2012...) must be improved or additional more complex approaches and tools must be used for taking into account all these indisputable issues (the German DGNB is already dealing with some of them, such as LCC).

The table 2 and graph 3 mention **the various issues of such a whole life value approach.**

Table 2 – Topics for a Whole Life Value Analysis

Whole life value dimensions	Definition of the analysis issues
1. Direct life cycle costing (Direct LCC)	Construction cost and other initial costs Building in use costs Maintenance and retrofitting costs Renewal costs (equipements, products) Residual value or demolition cost at the end of the building life <i>Measure of the benefit (using a life cycle cost analysis) compared to a reference (business as usual) building</i>
2. Contribution to climatic change	Greenhouse effect gas emissions during the whole life of the building (construction, building in use, demolition...) – Carbon stocked during the whole building life <i>Measure of the carbon net balance of the building</i>
3. Building completion respect	Time respect for the various phases: building construction, completion, duration of life...
4. Requirements compliance	Technical programme compliance Respect of the objectives in terms of social integration
5. Environmental quality	Climate change adaptation Water management Local, recycled or recyclable materials Low pollution building site

6. Quality in use (user)	Natural lighting quality Acoustic comfort Visual comfort Thermal comfort and summer comfort Agency quality (room sized, night and day area, lost space, additional spaces (balcony, terrace...)) Waste management (activity, household refuse...) Proximity of services and amenities, including public transport stations Bicycle box (on the first floor)
7. Quality in use (owner)	Maintenance management Use modification capacity of the building (during the building life time)
8. Health quality	Hygrothermal comfort Healthy conditions in the various spaces (ventilation, air renewal) Health quality of indoor air (in relation with the used materials) Health quality of water

Graph 3 - Whole Life Value Analysis

The dimensions (or issues) 1 to 3 (Direct LCC, Carbon and Time) need precise quantitative measures but the dimensions 4 to 8 need a qualitative analysis done with qualitative and quantitative indicators

This schema completes the schema of the Design Quality Indicator Tool (or Whole Life value Toolkit) worked out by the European Construction Institute (ECI) within a partnership between RICS, Constructing Excellence, CIC Design Quality Indicators, Faithful & Gould and Valid. Their schema has only 5 dimensions (Direct LCC, Time, Compliance, Environment and Building quality).

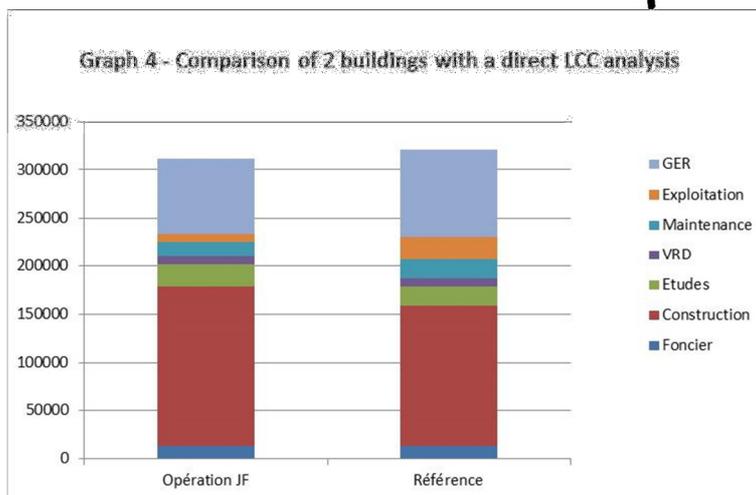
Source La Calade

Questions as regarding direct life cycle costing (Direct LCC)

Everybody is speaking about LCC and tells he uses to manage with such approaches since many years but in reality they don't do it because they have not any calculation method. The main difficulty of a direct LCC analysis is the calculation method. If technicians and engineers know rather well the impacts of their investment choices and are able to suggest solutions according to them, the building owner does not well know the maintenance conditions needed by the building's equipments and so he needs a LCC with a calculation method in order to be sûre of their choices (or to make other choices).

LCC calculation supposes too that there is not a unique solution to any problema but several solutions which may have also impacts on some qualitative aspects of the building (or of the retrofitting program).

LCC consists in a comparison between several solutions (as shown in the EPBD additional 244/2012 regulation which is often forgotten...) and so it can be easier during architects competitions within a call for tenders.



Source: La Calade for Ophis 63

Comparison between various technical solutions or systems is also possible, for example, as regarding energy choices, even if the technical system itself cannot be imagined without the building envelop choices (techniques).

Last, the LCC of a building (or of retrofitting works) can be compared to the LCC of another similar building, even if such a comparison is always difficult because each building is unique (as architects use to tell it...). Sometimes, investment overcosts are compared with expected savings but this type of analysis is not at all a scientific one and cannot be called a LCC...

So, the most appropriate solution seems to be the comparison between two or several building projects as regarding the same requirements. And the LCC analysis is improved during the designing phase according to the availability of costs and finalised when the market terms are well known and then during the Works themselves and the using phase (including retrofitting works).

Another important element in the LCC calculation is the way according to time is dealt with. For giving a value to time, we use the discount rate which is the mathematic calculation which allows bringing all the costs accruing during the building life. It allows to compare receipts and expenses which are carried out at different dates. But what value to give to the discount rate "a"?

In numerous case studies, we use the interest rate which is the capital price on the market (credit rate or investment) or the money value. We refer to a financial approach. In the private sector, "a" is the opportunity cost of the invested capital. "a" may be compared to the capital cost for the investor or to the return on investment (ROI) (interest+risk+margin). In public administration, risk is often not taken into account and there is no profit objective, so "a" is assimilated to the interest rate. But the bank interest rate cannot reflect the interest of next generations, it can only reflect the interest of people directly concerned by the project.

According to the economic theory and so to an economic approach, "**a**" *measures the time value* or the substitution rate between future and present time (or the present time preference): it reflects individual or collective preferences for the present time (present generation).

National authorities preconise a rate officially recognised as of benefit to the country. In France this rate is 4 % in constant euros for a 50 years calculation (3 % for the European Union). This rate does not include any economic risk. A 2.5 % risk premium should be chosen if the results of the works could bring difficulties (for renting the building or selling it for example).



This rate does not include either any ecological risk such as the climate change impact (it may on the contrary support choices which reduce long term impacts...). And so the Nicholas Stern review on the climate change cost advocates a social discount rate “a” of 1.4 %. A small discount rate as well as a long term period favour investments which the lowest maintenance and operating costs.

Conclusion

The economic crisis we have to manage with since 2008 and the necessary fight against the climate change have reinforced the need for including and assessing precisely all the economic parameters linked with building management as well as retrofitting and construction works, in respect with the requirements and delivery time, impacts on health and quality in use inside the buildings.

These elements contribute to measure the building green value which is up to now a theoretical concept. They also may become huge economic and social constraints for low income users or for users with limited financial resources. The Whole Life Value has to be integrated in land planning approaches (especially at the neighbourhood scale) for new buildings and retrofitting works, and it is the reason why the whole life value is included in INDI – 2015 (which will be available at the end of 2014 with examples of analysis).

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Integrated decision support tool in energy retrofitting projects for sustainable urban districts

Speakers:

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Abstract: *Energy retrofitting of buildings is envisaged as the most promising strategy to reach EU's "20-20-20" targets. However, the traditional approach to the building energy efficient retrofitting brings poor results in relation to urban sustainability, resource efficiency and economic return. The district retrofitting approach is frequently the most sustainable and cost-effective, but the selection of the most appropriate technologies and retrofitting strategies for each specific project can become very complicated due to the large amount of factors to be taken into account. The objective of the FASUDIR project is to develop an integrated software tool that supports decision making in retrofitting projects. The tool is based on a new methodology that will evaluate the global sustainability of the retrofitting scenarios, providing recommendations based on metrics and novel indicators to increase the energy efficiency, without penalizing and preferably enhancing the global sustainability, resource efficiency and the environment of the district.*

Energy efficiency, Energy building retrofitting, District sustainability, Decision support tool, Key performance indicators, GIS, CityGML

Introduction

The building sector has enormous impacts on our environment and the influence of building performance on broader sustainability is widely acknowledged and based on indisputable facts [1]. Furthermore, the importance of the construction sector is not only manifested in its impact on the environment but also on the level of society considerations. Construction practices affect core issues such as accessibility, comfort, health, safety and security.

Therefore a paradigm change has to start in the building sector: with a minimum input of energy and resources, the best economic efficiency, comfort and architectural performance have to be achieved and be brought into the planning processes [2].

In Europe more than the 70% of the building stock was built before the first energy crisis and one-third of the dwellings are more than 50 years old [3]. According to recent studies [4], in order to meet Europe 2020 and 2050 energy, carbon and economic goals, 3% of the total EU building stock would need to be deep-renovated each year for the next 40 years. Although the retrofitting of the building stock is very slow [5], renovation is envisaged as a key strategy [6] to reduce the energy impact of the building sector (with a longer-term perspective on the development of a green construction economy underpinned by a healthy retrofitting industry [7]), and consequently it has to be encouraged and a new more efficient and systemic retrofitting approach is needed.

The current approach to building retrofitting (where buildings are managed as isolated objects, ignoring the interaction between them and the district scale) brings poor results in



relation to the urban sustainability, resources efficiency and economic return. Although the district retrofitting approach is frequently the most sustainable and cost-effective, the complexity of decision making grows exponentially when the intervention targets larger scale, even more when considering the fragmentation of the construction sector. The main reason is due to the multiplied difficulty of analysing all the involved factors (economical, technical, social, etc.), and the interaction between them, in order to define the best retrofitting approach at district scale. Also the number of stakeholders (owners, municipality, investors ...) involved in the process is greater and a consensus between them on the interventions to be deployed has to be achieved, increasing the complexity of decision making. Consequently, there is a need for an interactive and user-friendly decision support tool that enables analysis of the impact of the building energy oriented retrofitting project on the sustainability of the urban district in a holistic way, facilitating the necessary communication mechanisms that can forge agreement between the multiple stakeholders that are involved in this process.

In order to satisfy this need, and to foster energy efficient retrofitting of buildings for sustainable urban districts, the FASUDIR project (Friendly and Affordable Sustainable Urban Districts Retrofitting) will develop new business models and financial supporting tools, to support the necessary building-retrofitting market mobilization in Europe to fulfill EU-targets in 2020 and 2050. The key instrument will be the Integrated Decision Support Tool (IDST), developed to help decision makers to select the best energy retrofitting strategy to increase the sustainability of the whole district. With stakeholder feedback loops, [training](#), and validation in [three diverse urban areas](#) (Santiago de Compostela, Frankfurt and Budapest), the IDST will ensure robustness and applicability in the entire value chain.

Integrated Decision Support Tool framework

The FASUDIR project (www.fasudir.eu) will provide an Integrated Decision Support Tool (IDST), based on a new methodology supported by a software tool. The IDST will consider the district as a whole energy system to improve the efficiency of the global energy balance, through a holistic and cross-disciplinary approach. Therefore it will be able to identify the most appropriate measures, whatever the technical, political, environmental, legal, financial and commercial issues that apply in a national context.

Retrofitting processes can be triggered by different stakeholders, but independently of who initiates the retrofitting process, in most cases there needs to be a close interaction between several of these stakeholders. Urban retrofitting activities at district scale are guided by urban plans and intervention priorities, defined by the Municipalities (Urban Managers), that identify the areas that need to be upgraded because their physical/social/environmental degradation. At the same time, Urban Managers can create an energy model of each of the districts in the Municipality for a better and integrated management of the city. Grants Managers provides incentives for investors and owners to boost the renovation activities and to make more attractive the investment opportunities. These incentives are often based on energy and environmental performance targets, assessed by means of evaluation/certification schemes/tools. Users benefit from the retrofitting activities obtaining at the end of the process

more efficient buildings. Owners and investors/developers rely on architectural/engineering firms (Technical Staff) to design and develop the best retrofit actions that concern their constructions/infrastructures. The Technical Staff are able to propose the best available solutions (materials, technical installations, etc.) on the market, from a cost-efficiency point of view, interacting with the Building Solutions Suppliers. Interactions between stakeholders are often bi-directional. Investors and owners could ask the Grant Managers to foresee an incentive or they could propose to the Municipality to modify the urban plan to allow a retrofit activity. All these interactions are quite complex to manage. This is the scope of the IDST tool that will be used to manage the process in an effective and goal driven way.

The IDST will focus on the initial stage of the retrofit process at district level, in which the retrofit framework is established (the strategies are defined and the technological solutions are selected). The IDST will be designed to select and prioritise energy efficiency retrofitting interventions and will allow selecting the optimal, off-the-shelf technologies and strategies for each specific energy retrofitting project in terms of sustainability as a whole (environmental, economic and social). Taking into account the different European urban typologies and the priorities of the decision makers, the IDST will guide in the selection of the best energy retrofitting strategy to increase the sustainability of the whole district.

Figure 1 shows the interaction between the IDST results and the main actors involved in retrofitting projects at urban scale:

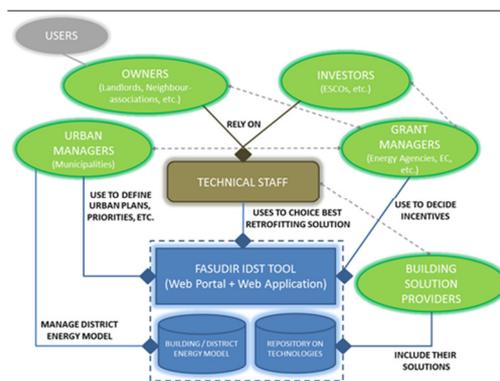


Figure 1. IDST interactions with the main stakeholders involved in retrofitting projects at urban scale

Decision Support Tool methodology

A novel methodology will be developed for selecting and prioritizing energy efficiency retrofitting interventions based on existing and new cost-effective solutions, for significant sustainable improvements in the rehabilitation of urban districts. It will address interventions that increase the energy performance of the buildings through a district level approach, including specific interventions for each building and interventions that take advantage of the district, as the synergies among buildings (complementarity of building uses...) and the integration in the district networks (district heating, gas network, electric network...).

The methodology will take into account the different urban typologies that are common in European cities and also the priorities of the decision makers. It will support retrofitting actions that are deployed as a unique intervention, but also scheduling sequential interventions in the most cost-effective way.

Figure 2 describes the IDST methodological approach to the energy efficient retrofitting and renewal of existing buildings for sustainable urban districts:

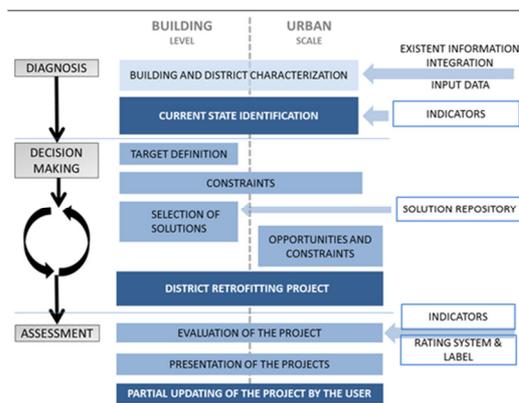


Figure 2. IDST methodological approach

The decision support tool methodology follows the next steps:

1st Phase: Diagnosis and current state evaluation

1. Characterization of the buildings and districts from the energy performance and sustainability point of view: In the first step all the information needed to define the object of the assessment is collected with the data that are required in relation to the buildings and district definition in order to assess their current levels of sustainability and energy efficiency (i.e. building and urban morphology, ownership, adopted building solutions, buildings uses, population, energy mix of the country, climatic conditions, existing service networks, ...).
2. Identification of the current state in relation to urban sustainability: In order to evaluate the current state, a set of key indicators (LCA, LCC ...) are compiled. An accurate diagnosis of the building and district will allow for the prioritization of the interventions in the second phase of the methodology. This set of indicators will take advantage of those already defined in previous R&D projects (OPEN HOUSE [8], SuPerBuildings [9] ...) and sustainability Certification schemes (LEED-ND [10], BREEAM-Communities [11], Protocollo ITACA [12] ...).

2nd Phase: Decision making and project design

3. Definition of the targets that will drive the decision making process: The selection of the sustainable target(s) that decision makers prioritize (high certification rating with the less investment, high energy efficiency with low LCC) will fix the priorities of the selected solutions.



4. Constraints definition: The feasibility of these targets will depend also on the specific constraints of each project. The categorization of the building and district developed during the project in addition to the definition of the legal, socio-economic, cultural, political, technical and environmental country requirements will assist the definition of the boundary conditions.
5. Definition of the district retrofitting project through the selection of the best solutions for improving urban sustainability by means of building retrofitting: The selection of the best solutions based on optimisation calculations will be carried out in a three-step process:
 - a. The number of individual solutions to be taken into account will be filtered based on the boundary conditions (previous defined constraints, local weather conditions, patterns of use ...).
 - b. Selection of the best energy efficient solutions for retrofitting at building level:
 - i. Generation of a set of realistic interventions.
 - ii. Simulation of the energy performance and sustainability indicators.
 - iii. Optimisation solutions based on users' objectives.
 - iv. Rating of the results.
 - c. Improving the efficiency of the solutions at building level by means of the district level approach. This stage could imply a fine tune rethinking of the interventions both at building and district level.

3rd Phase: Project assessment and update

6. Evaluation of the sustainability of the district retrofitting project: Based on the previous referenced key indicators, the upgraded sustainability of the retrofitted buildings and districts will be evaluated.
7. Impact of the retrofitting projects within existing district networks: The impact of the retrofitting projects will be evaluated, in order to identify potential infrastructure weakness and the needs for upgrading.
8. Presentation of the best district retrofitting projects: The most sustainable and energy efficient retrofitting projects at urban scale will be presented: solutions + sustainability indicators.
9. Partial updating of the project by the user: The user will select one of these scenarios and will allow editing it in order to evaluate the impact of minor changes in the sustainability and energy efficiency of the district

Decision Support Tool

The software tool that will support this methodology will perform the required calculations to evaluate the districts energy and sustainable performance and help in the process of energy efficient districts retrofitting. It will be based on seamless integration of both scales (district and building) through a unique data model based on CityGML standard, which represents a 3D City model at different levels of detail. It will combine the high potential of GIS tools for urban sustainability analysis with energy performance evaluation at building level. All the

information will be accessible through a unique and coherent data model which includes both geometric and semantic information.

The tool is built upon a base of existing softwares and will be enhanced by more informed algorithms and most importantly of all, integrated to provide synergistic solutions at the district level which provide the user with more insight and powerful decision making.

The software tool will comprise a set of four inter-related modules based on a client-server architecture. Figure 3 represents the overall system description of the IDST software tool and the main external inputs and dependencies:

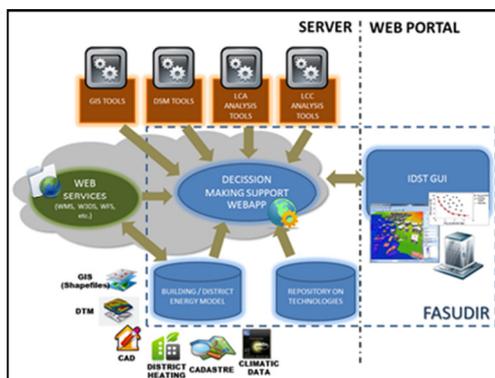


Figure 3. Global architecture of the IDST software

- **Building and District Model.** This CityGML based module will enable modelling the district and building with an adequate level of definition. In order to simplify the building and district definition process two complementary strategies will be adopted:
 - Importing already existing data: morphological factors (size, volume, urban density, etc.), service networks, land registry.....
 - Editing the missing data by the user.
- **Sustainable Retrofitting Technical Solutions.** This module will contain a collection of sustainable retrofitting strategies and technical solutions at building and district level.
- **District Sustainable Retrofitting DST.** This module will be the core of the IDST and will provide the following functionalities:
 - Evaluating the sustainability of each building.
 - Evaluating the sustainability of the district.
 - Suggesting the most promising sustainable retrofitting strategies and technical solutions at building and district level.
 - Managing different retrofitting scenarios.
 - Mapping the IDST sustainability assessment to similar already existing sustainability certification labels.
- **Graphical User Interface.** To make the definition of the retrofitting scenarios and understanding the evaluation results more straight forward and intuitive, a graphical user interface will be adopted. It will allow the interaction at building level and at district level.



Conclusions

The FASUDIR project was born to develop new business models and financial supporting tools, to support the necessary building-retrofitting market mobilization in Europe to fulfill EU-targets in 2020 and 2050. The key instrument will be the [Integrated Decision Support Tool \(IDST\)](#), developed to help decision makers to select the best energy retrofitting strategy to increase the sustainability of the whole district.

The proposed tool will give a holistic view to the Governments, Municipalities, decision makers, engineers and in general to the stakeholders involved in the urban planning about the existing possibilities as well as the constraints that they will have to face when retrofitting the district or the community. IDST aims to be a decision tool that will allow Authorities to introduce energy efficiency measures, renewable energy technologies and other energy-related actions in the development of districts retrofitting. The IDST will give the means to help the stakeholders involved in the district retrofitting to fulfil this commitment.

Acknowledgements

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Session 88:

Which are the limits of life-cycle assessment as a rating tool to evaluate sustainability in building? (III)

Chairperson:

Macías, Manuel

Profesor/Responsable del área de Investigación. Universidad Politécnica de Madrid/GBCe



Simplified and reproducible building Life Cycle Assessment: Validation tests on a case study compared to a detailed LCA with different user's profiles

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Abstract: *The Life Cycle Assessment (LCA) is a methodology to evaluate the building environmental impacts for the production, use and end-of-life phases. Two main barriers still limit the LCA to be largely used in the construction sector: time-consuming approach and non reproducible results between practitioners. In this study, we present a combined approach to conduct reproducible and simplified building LCAs. The simplified methods were defined based on the target group needs (e.g. construction companies). Each approach decreases the degree of freedom for the users while focusing on the main impact sources. Results show a deviation of results no more than 20% between the complete and simplified LCA methods. A better reproducibility between users is found for the simplified methods due to the predefined parameters (in opposite to the complete LCA). In addition, considerable time saving was reported. Our proposal should now be applied to a bigger sample of professionals of the construction sector to collect more feedbacks.*

Keywords: LCA, embodied impacts, buildings, simplification, reproducibility

1. Introduction

The Life Cycle Assessment (LCA) is more and more recognized as a relevant methodology to evaluate the building environmental impacts for the production, use and end-of-life phases. It has been applied in the construction sector for many years and led to the development of several LCA softwares in Europe [1] [2]. Two main barriers still limit the LCA to be largely used with confidence in the construction sector. First, it is due to the time-consuming of a complete LCA study, especially for the assessment of the embodied impacts related to construction products integrated in a building. Unlike simple manufactured products, a building can be breakdown in dozens or hundreds of elements. Secondly, without detailed rules, we can still find very different results between two users on the same LCA tool depending on the chosen system boundaries, the quality of the bill of quantities, the user profiles and experiences. Previous studies already showed that the LCA embodied impacts for buildings can diverge due to the different scope of the modelling e.g., different boundaries, different LCA data, different representativeness of the studies [3]. A first requirement to harmonize LCA practice in the building sector is to rely on the same scope. In Europe, a first contribution was provided by the CEN TC 350 committee, which released two standards on products and buildings LCA [4]. In addition, a recent operational guidance InfoHub for building LCA (derived from the EeBGuide project) recommends using the EN 15804 and EN 15978 standards in the LCA practice [5]. The EeBGuide outcomes also proposed to go further



by developing different study types (screening, simplified and complete LCA) in a building LCA tool according to the stakeholders' needs [6].

In this paper, we are interested in deepening the EeBGuide proposal for simplified LCA of a building. The interests of a simplified LCA method are mainly the reduction of the modelling time and the improvement of reproducibility between different users of the tool, due to the definition of harmonized parameters e.g., for LCA data or system boundaries. The simplified solutions have to be adapted to the user profiles and should be provided with guidance to be used in decision making. Moreover, the simplification should not decrease the accuracy of the global LCA results by keeping the sensitivity of results to major design parameters. Indeed, the simplification rules should be focused on the LCA tool interface by provided the limited number of parameters, based on empirical knowledge (e.g., previous LCA results of buildings can lead to the identification of the main impact sources and the simplified LCA method can benefit from them). In this study, we present a collaborative work with a LCA tool developer and a construction company conducted in the framework of a national research project [7]. A combined approach is proposed for reproducible and simplified building LCAs.

2. Scope of the study

The simplified LCA methods are only developed and applied on new multi-residential buildings. This building type, in Europe and in France, mainly represents low energy buildings e.g. consuming less than 50 kWh/m²/year for the regulatory uses of the thermal regulation (heating, cooling, domestic hot water, lighting, auxiliaries).

2.1. System boundaries

According to the EN 15978 standard "Sustainability of construction works, assessment of environmental performance of buildings, Calculation method", module A (impacts related to the production of a product, its transport and the loss of the product on-site), module B (the number of replacement rates linked to the maintenance actions considered) and module C (end-of-life) are considered for the impacts related to the building products and technical equipment". Figure 1 presents the system boundaries in relation to the three study types (screening, simplified and complete LCA) and the building type. This figure is derived from the EeBGuide InfoHub for building LCA [5]. Table 1 presents the nomenclature used to classify the elements according to the "HQE Performance" application rules [8].

2.2. LCA data used

Generic LCA data for building products and technical equipment are used in this study. These are based on Environmental Product Declaration (EPD) available in the national reference database INIES [9]. EPD are sector-specific LCA data, describing the impacts of one or several manufacturers that sold their products on a national market (e.g. the French market). When some EPD are missing for some products or equipment, generic data from the ecoinvent database are used. The generic LCA data based on EPD or ecoinvent are calculated following the NF P01-010 and EN 15804 standards from cradle-to-grave (i.e. for modules A, B and C cf. Figure 1) [4].

Table 1: Nomenclature used to classify the elements according to the HQE Performance application rules

Classification of the building elements in 14 parts
1. External work
2. Foundations - infrastructure
3. to 7. Building products associated to the building envelope (superstructure)
Structural elements
Roof elements
Interior walls
Windows and joinery work
Interior finishes
8. to 14. Technical equipment
HVAC
Sanitary facilities
Electricity and communication network
Safety equipment
Lighting
Lifts
On-site electricity generating units (wind power, PV panels)

2.3. Environmental indicators

Seven indicators were used based on the French and European standards for LCA in the construction sector. Table 2 presents the names, units and abbreviations of these indicators.

Table 2: List of environmental indicators considered in this study

Indicators	Abbreviations	Units
Total primary energy	PE	kWh
Water consumption	WC	l
Waste production	WA	kg
Radioactive waste production	RW	kg
Global Warming potential	GWP	kg eq-CO ₂
Acidification potential	AP	kg eq-SO ₂
Photochemical ozone formation potential	POCP	kg eq-C ₂ H ₄

3. Development of simplified LCA methods

Figure 1 presents the goal and scope of the simplified LCAs (cf. section 2) in relation to the targeted users' group (construction companies). The simplified LCA methods are developed based on the outcomes of the EeBGuide InfoHub for building LCA. Screening and complete LCA are also reported to be consistent with the EeBGuide LCA guidance but are not described in this paper. The following requirements taken into account in the development of simplified LCA methods are as follows:

- Keep a good level of accuracy for the simplified LCA compared to a detailed LCA
- Reduce LCA modelling time by focusing on the main impact sources or on default values
- Involve third-party (e.g. a building stakeholder) to match the simplified LCA method to the user needs

Improve the reproducibility of LCA results by defining harmonised and predefined LCA data or system boundaries so that different practitioners can still achieve a similar LCA result (in opposite to complete LCA with a higher degree of freedom). With these key requirements in mind, the next sections present two simplified LCA calculation rules for the assessment of embodied impacts of new multi-residential buildings. They are the results of collaboration between a LCA tool developer (CSTB) and a building stakeholder (Bouygues Construction).

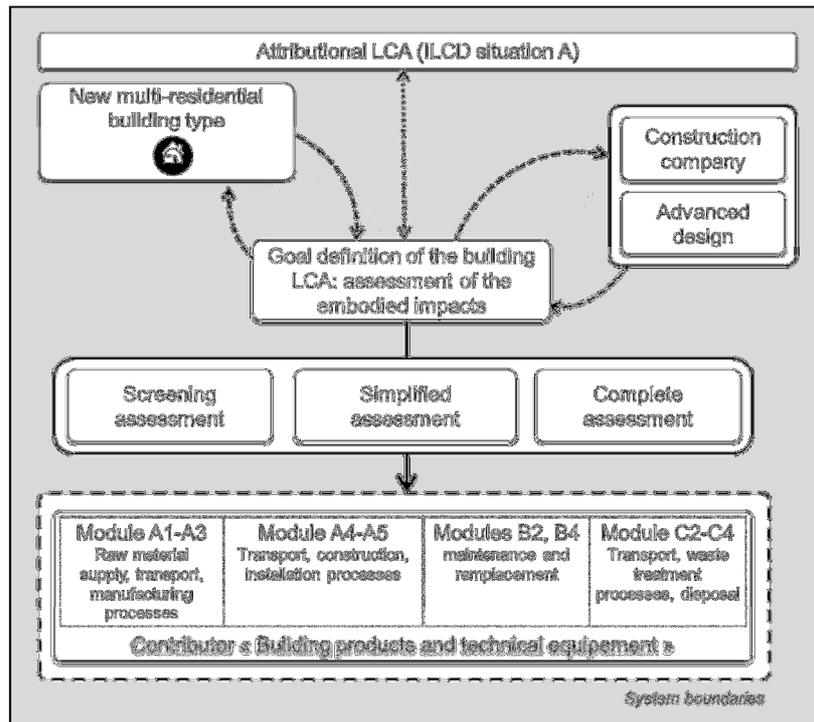


Figure 1: Goal and scope for the simplified LCA methods in relation to the targeted users’ group for the contributor “building products and technical equipment”

3.1. Pareto simplified LCA method

The simplified LCA method “Pareto” is based on the general principle stating that “80% of the consequences are linked to 20% of the causes”. In LCA, it means, for a same building type, that only a limited number of building elements significantly contributes to a given environmental impact (e.g. the global warming).

The Pareto calculation rules can be breakdown in three parts:

- First, the definition of a reduced LCA using a harmonised and predefined list of elements associated to generic LCA data.
- Second, the calculation of ratios derived from the complete and reduced LCA results
- Third, the reduced LCA results per indicator are multiplied by the statistical ratios in order to compensate the neglected elements leading to the simplified LCA method “Pareto”.

In step 1, the elements that are mainly impacting in multi-residential projects are identified for instance reinforcing steel, foundation concrete and superstructure concrete. For the same

system boundaries (see Figure 1 and Figure 2), several building LCA case studies are conducted to derive the statistical ratio between the complete and the reduced LCAs. Ratios R are derived using the following formula:

$$I_{\text{simplified LCA}} = 1 - \frac{I_{\text{reduced LCA}}}{I_{\text{complete LCA}}}$$

Then, the ratios are applied to the reduced LCA results to convert them in simplified LCA results “Pareto”. The statistical ratios applied enable to keep the same level of completeness compared to a complete or detailed LCA while reducing the time spent by the practitioners.

3.2. EMMA simplified LCA method

The simplified LCA method “EMMA” is based on the general principle arguing that the quantities of elements implemented in a building are linked to global parameters defined in early design stages e.g., net floor surface area, number of storeys, windows surface area, number of flats in a residential buildings. We mention that such approach has been used for many years in cost studies, by general contractors willing to reduce time spent in response to call to tenders. Here, the same approach is transferred to the environmental accounting.

The EMMA calculation rules can be breakdown into three parts:

- First, the definition of a list of elements
- Second, the building parameters that are linked to the elements (e.g., number of storeys etc.)
- Third, statistical ratio of quantities based on empirical knowledge within the construction company (e.g., taken from cost studies)

These three aspects can be determined from bill of quantities, invoices, or feedbacks from previous projects of the same building types. Yet, the overall reliability of this simplified LCA method will rely on the sample size of previous projects, and on the sound analysis of relationship between the building parameters and the quantities of elements. Main relationships for multi-residential buildings (mostly built in reinforced concrete in France) can be per linear, surface area or units of building elements. For instance, from the linear of facades, it is possible to have a proxy of the surface area of the facades based on the heights of each storey. Then, an automatic estimation of quantities of concrete, steel, insulation, interior coating can be derived (valid for loadbearing concrete structure). Similarly, the separation between wet and dry rooms in the building lead to two types of surface area also leading to the determination of cover floors (e.g., soft cover floors for dry rooms and ceramic tiles for wet rooms). Finally, quantities of elements can be derived from unit of equipment e.g., for HVAC. In that case, the statistical ratio of material quantities can be adjusted to the type of heating or ventilation system. In the end, a reduced amount of early design parameters enable to quantify all the elements. Then, a generic LCA data is associated. Then, the simplified LCA provides the same level of completeness as a complete LCA though with less

effort. This method is well fitted for early ecodesign approach, because it is easier to compare different scenarios or variants.

4. Results

The two simplified methods have been implemented in the ELODIE® LCA software for buildings [10]. The results presented in this section concern the assessment of the embodied impacts of a real project of two multi-residential buildings located in France (see Figure 2). The net floor surface area is 4687 m² and each building has six levels above the ground and one underground car park. The LCA results are expressed per m² of net floor area per year. The baseline reference study period (RSP) is set at 50 years.



Figure 2: 3D view of the building in advanced design

4.1. Validation of the two simplified LCA with detailed LCA on the building case study

Figure 3 presents the deviations in % between the simplified methods and a complete LCA. We notice a fairly good accuracy of the two simplified LCA methods with systematically more than 80% of the results of the detailed LCA. The POCP and WA indicators present the lowest level of accuracy for the Pareto method with 85% while for all the other indicators the error margin does not exceed 10%.

Comparison Detailed LCA and Simplified LCA (Pareto and EMMA)

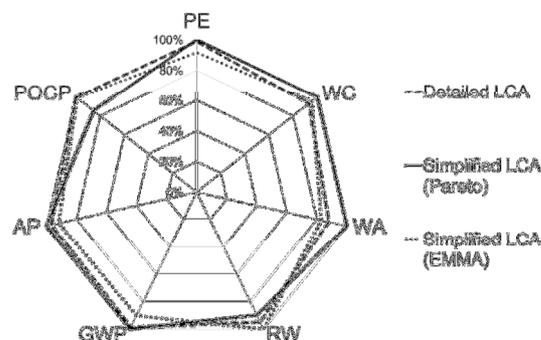


Figure 3: Results' deviations between a detailed LCA and the two simplified LCA methods

4.2. Reproducibility tests of the two simplified LCA methods with different user profiles

Results from Figure 3 show a fairly low loss of accuracy between the two simplified LCA and the detailed LCA. Figure 4 now presents a first pilot-test conducting on a sample of different

user profiles from a construction company. Nine different users representing different profiles in the construction company’s stakeholders (e.g., LCA practitioner with low experience vs. high expertise etc.) were asked to model the multi-residential building case study using these simplified methods. They use the same building design documents (program, plan, costing). Results of the case study showed a fairly good reproducibility when using these simplified tools and detailed guidance. The reproductibility with EMMA and with PARETO is quite similar.

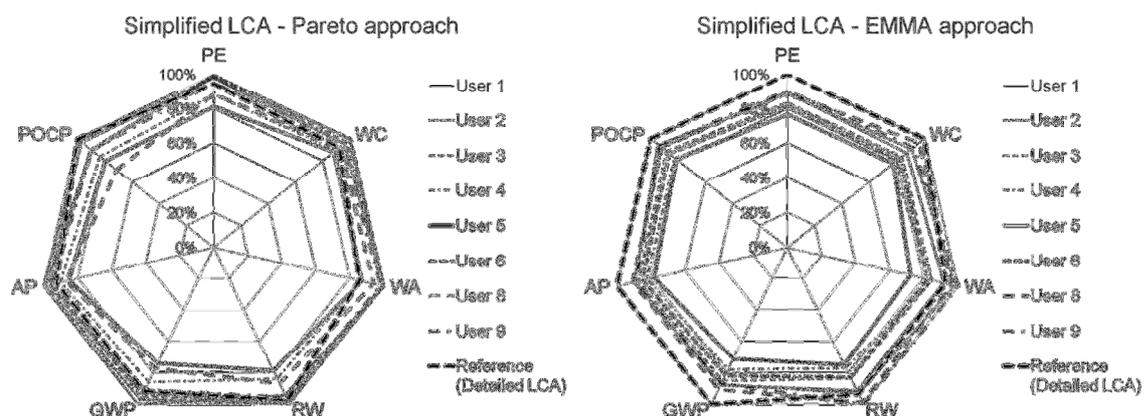


Figure 4: Results’ deviations between the different user profiles for the two simplified LCA methods

Conducting simplified LCA also avoid spending a lot of time modelling elements per elements the building. As an illustration, Table 3 presents the average time needed for the different practitioners.

Table 3: Average time spent by the different users for each type of LCA (complete, Pareto and EMMA) in the multi-residential case study

Indicators	Average time spent
Complete LCA	12 hours
Simplified LCA – Pareto	3 hours
Simplified LCA – EMMA	8 hours

We notice that the time allocated by the construction engineers to the LCA drop from 33% with the EMMA simplified LCA to 75% with the Pareto method. As stakeholders cannot afford much time to conduct a LCA study especially in early design, such a compromise between accuracy, data requirements and efforts (time and cost) is probably the best method to invite more building stakeholders to the LCA approach.

Further works should now be conducted to propose whole simplified LCA of building taking into account the embodied impacts but also the operational water and energy consumption. Similarly, further simplified LCA methods should be proposed to match the needs of other stakeholders (e.g. architects, thermal analysis design office etc.).



Conclusions

This paper presents a contribution towards simplified LCA following the general provisions and guidance of the EeBGuide European InfoHub on building LCA [5]. Simplified LCA is needed in construction LCA practices as practitioners do not have a lot of time to assess the environmental performances of their projects. This study showed the feasibility of simplified LCAs. Considerable time saving was reported between a simplified and a detailed LCA while keeping a fairly good accuracy. It would now be useful to validate the simplified LCA tools with a bigger sample of professionals of the construction sector to collect more feedbacks. In the same time, even if useful in early design or in quick LCA of new buildings, the practitioners should remain aware that the results of the simplified LCAs present a substantial uncertainty due to the reduced level of description of his project. However, if more time or more information is available, the practitioner will be able to precise the modelling and thus decrease the level of uncertainty linked to the level of description of the project.

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Results of DGNB certified sustainable buildings. Austrian case study focussing on the environmental life cycle performance (LCA).

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Abstract: *The aim was to compare the environmental life cycle performance of DGNB certified buildings and of other demonstration buildings in order to adjust the benchmarks and to revise the applicability of the DGNB assessment for other regions. The impacts of building materials and operational energy have been compared regarding existing benchmarks and improvement potentials. The question was, if the proposed adjusted benchmarks show the quality of the building regarding resource efficiency and environmental protection. Results of the analysis show that the operational energy has the highest environmental impact. Comparisons with other best practice buildings resulted in adjusted benchmarks, especially regarding target values linked with the operational energy. The recast of the rating tool emphasises on adjusted benchmarks for environmental life cycle criteria. Recommendations for a higher transparency of the results and for a better applicability to other regions and countries are given.*

Keywords: *DGNB, certification, LCA, benchmarks, energy efficiency*

Introduction

Since 2010 the Sustainable building certification system DGNB is in use in Austria. The Austrian Sustainable Building Council (ÖGNI) was founded in 2009, cooperates with DGNB-Germany and adapted the German certification system for sustainable buildings to Austrian conditions [1]. Results of the first certified buildings have been presented on SB13 in Graz [2]. Meanwhile, about 50 buildings were certified by ÖGNI. This paper focuses on the results of environmental life cycle assessments in order to obtain benchmarks for the future development of the rating system. The DGNB/ÖGNI Certificate is a transparent and comprehensible rating system, which is based on the CEN/TC 350 approach. It defines the performance of buildings in a comprehensive way with 5 weighted topics plus 1 additional topic: environmental quality (22.5%), economic quality (22.5%), socio-functional quality (22.5%), technical quality (22.5%), quality of process (10%) and – an additionally not weighted, separately evaluated topic – quality of the location. For environmental quality the criteria set of environmental life cycle assessment has the biggest influence with 13.5% share of the overall score.

Methodology

The objective of this investigation was to learn from the first certified buildings for the development of the assessment system. Meanwhile, about 50 buildings were certified by ÖGNI and an update of the assessment system is developed currently. Therefore the results of



DGNB/ÖGNI certificated buildings have been analysed in order to derive conclusions for a fine-tuning of the criteria set and the benchmarks. The investigation includes 23 certified offices buildings that had been certified between 2010 and 2013. Further information regarding these buildings can be found in the contribution of Neururer et al. for WSB14 [3]).

The methodology for environmental life cycle assessment is according to EN 15978. The product stage (modules A1-A3) is calculated with the German Ökobau.dat-database version 2009, which is based on the GaBi-database. The use stage (module B6) is calculated with the Austrian energy certificate according to OIB directive 6 [4] and by a scenario for replacement (module B4) according to the Austrian service life catalogue [5]. The end-of-life stage is calculated with a scenario for waste processing and disposal (modules C3 and C4) with the Ökobau.dat-database. Benefits and loads beyond the building life cycle (module D) are included in the assessment by a scenario for recovery of metals and mineral materials and for thermal recovery of materials with a heat value. Other modules of EN 15978 are neglected or regarded within other DGNB criteria. The temporal system boundary is determined by a reference service period of 50 years.

The DGNB rating system includes the following environmental indicators of EN 15978: Global warming potential (GWP 100), ozone depletion potential (ODP), photochemical ozone creation potential (POCP), acidification potential (AP), eutrophication potential (EP), non-renewable primary energy use (PE-NR) and total primary energy use (PE). Additionally the share of renewable primary energy (% PE-R) is included in combination with the assessment of the total primary energy use.

The results of the statistical analysis were presented in boxplots, showing maximum values, minimum values, mean values, upper quartile and lower quartile. That means that 50 % of the results lie within these boxes. Further analysis of the LCA was restricted to GWP and PE-NR (due to the page limit) and operational energy. These results were presented anonymously in ascending order and compared with data of selected demonstration buildings [6], [7], [8], [14] (see table 1).

The measured operational energy and its impact values (calculated with the conversion factors for the Austrian DGNB system) are shown. Additionally the old benchmarks (target, reference and limiting values) as well as the proposed new benchmarks are illustrated. New benchmarks were derived from:

- Energy consumption values [9], [10] with a share of floor area according to the example in [10, page 18].
- Austrian documents [11], [12] according to the European Energy Performance of Buildings Directive (Directive 2002/91/EC, EPBD)
- Updated benchmarks for materials according to the German DGNB version 2013

The calculation parameters of the proposed benchmarks for operational energy are:

- Target values:

- Demand class “very low” regarding electricity consumption values for cooling, ventilation and lighting [9]
- Useful heating demand according to Passive House Standard
- District heating supply for space heating and hot water
- Reference values:
 - Demand class “low” regarding electricity consumption values for cooling, ventilation and lighting [9]. This corresponds to the limiting values quoted in [9], [10], which should be complied with in new buildings and installations to be modernised.
 - Useful heating demand according to the limiting values of the Austrian Building Code [11] valid since 2012/2013: 28 kWh/(m².a) for a surface-volume-ratio of 0,25 m⁻¹ and a height of floors of 3 m.
 - Fossil gas supply for space heating and electricity for hot water
- Limiting values: 1,4-fold of reference values

In order to check the suitability of the proposed benchmarks, the results for operational energy of several best practice buildings have been analysed.

Table 1: Selected office buildings in Austria and Germany with very high energy efficiency.

#	Building	Location	Architect	Compl.	NFA [m ²]	S-V [m ⁻¹]	Source
1	Lamparter	DE-Weilheim	weinbrenner.single	1999	1.488	0,40	6
2	BOB	DE-Aachen	Hahn Helten	2001	2.151	0,37	6
3	NIZ	DE-Braunschweig	PSP	2001	8.570	0,17	6
4	Fhg-ISE	DE-Freiburg	Dissling + Weitling	2001	14.001	0,31	6
5	ECOTEC	DE-Bremen	Hahndorf , Wucherpfennig	1997	3.436	0,31	6
6	DB Netz	DE-Hamm	Architrav	1999	5.974	0,27	6
7	Pollmeier	DE-Creuzburg	Seelinger & Vogels	2001	3.510	0,32	6
8	SOL4	AT-Mödling	Solar4you	2005	2.245	0,38	7
9	Eine Welt	AT-Niklasdorf	Poppe Prehal	2009	2.267	0,37	7
10	Christophorus	AT-Stadl Paura	Böhm, Frohnwieser	2003	1.215	0,39	7, 14
11	Lehmhaus	AT-Tattendorf	Reinberg	2004	315	n.s.	7
12	Energybase	AT-Vienna	pos	2008	7.500	0,22	8, 14

Remarks: # = Sequence in Fig. 4 + 5; Compl. = year of completion; NFA = Net-Floor-Area; S-V = Surface-Volume-Ratio

Results

Eight office buildings were awarded with a Gold-Certificate, 13 buildings with a Silver-Certificate and two buildings with a Bronze-Certificate. The results (figure 1) show the percentage of the performance value. With an overall performance of more than 80 % a Gold-Certificate is reached and with an overall performance of more than 65 % a Silver-Certificate is reached. The highest results in average were reached for economical quality (89 %). The

lowest results in average were reached for process quality (65 %) which is due to the introductory phase of DGNB-Certification in Austria: For the first certified buildings the decision for certification was made in a relatively late project stage and therefore process quality criteria concerning earlier project stages couldn't be influenced or improved.

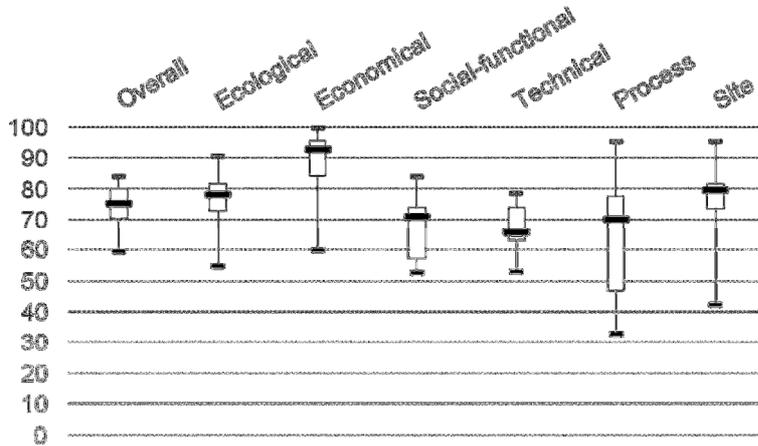


Fig 1: Boxplot of overall scores and partial results of 23 DGNB-certified office buildings. Performance values 0% - 100%. Minimum, maximum, median, upper quartile and lower quartile.

Figure 2 shows the results of the environmental life cycle assessment. Most of the buildings reached relatively high results especially concerning primary energy criteria. Many buildings reached better LCA results than the target values.

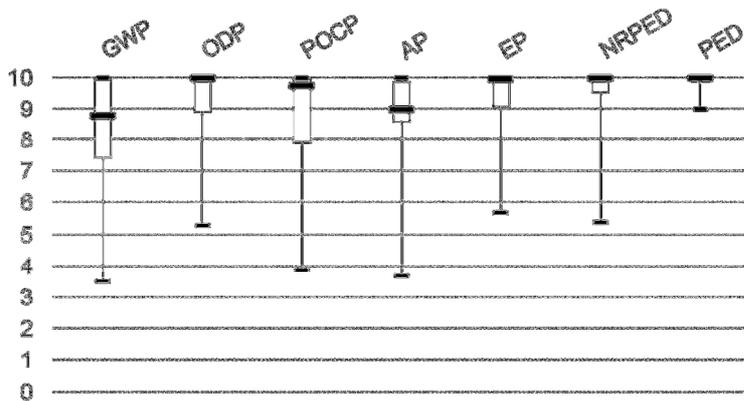


Fig 2: Boxplot of environmental life cycle assessment results. 0 – 10 assessment points. Minimum, maximum, median, upper quartile and lower quartile.

- GWP global warming potential,
- ODP ozone depletion potential,
- POCP photochemical ozone creation potential,
- AP acidification potential,
- EP eutrophication potential,
- NRPED nonrenewable primary energy demand,
- PED total primary energy demand and share of renewable primary energy

The following figure (fig. 3) shows the results and benchmarks for materials, summarizing product stage, replacement and end-of-life. For GWP the results fit very well with the benchmarks (beside for one outlier), which therefore have been adjusted only marginally. Results of PE-NR are all below the previous target value, but the new German benchmarks fit quite well (beside for three outliers).

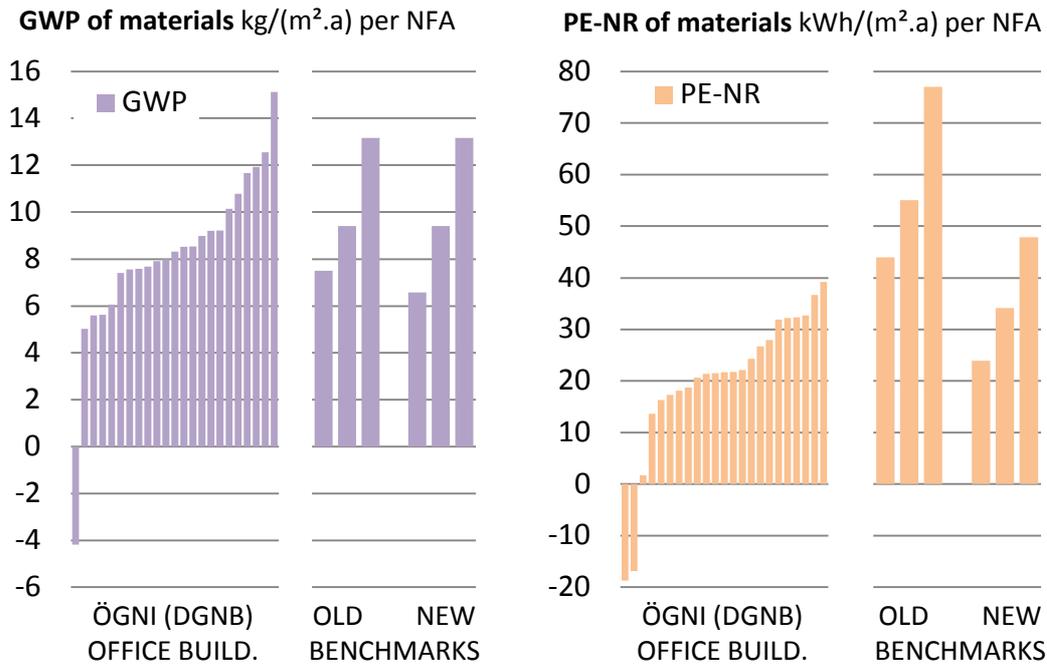


Fig 3: Global warming potential and non-renewable primary energy demand of DGNB certified office buildings in Austria. Impact of building materials (production, replacement and end-of-life) per net-floor-area. Compared with old and new benchmarks: target, reference and limiting values.

Figure 4 shows that all results (except one building) were more than 20 % better than the reference value for GWP and PE-NR. The comparison with the measured performance of demonstration buildings shows that the old benchmarks were not appropriate to show the higher quality of these buildings, because there are no bonus points if the building is better than the target value. That is, the amount of this overshooting has no influences on the results.

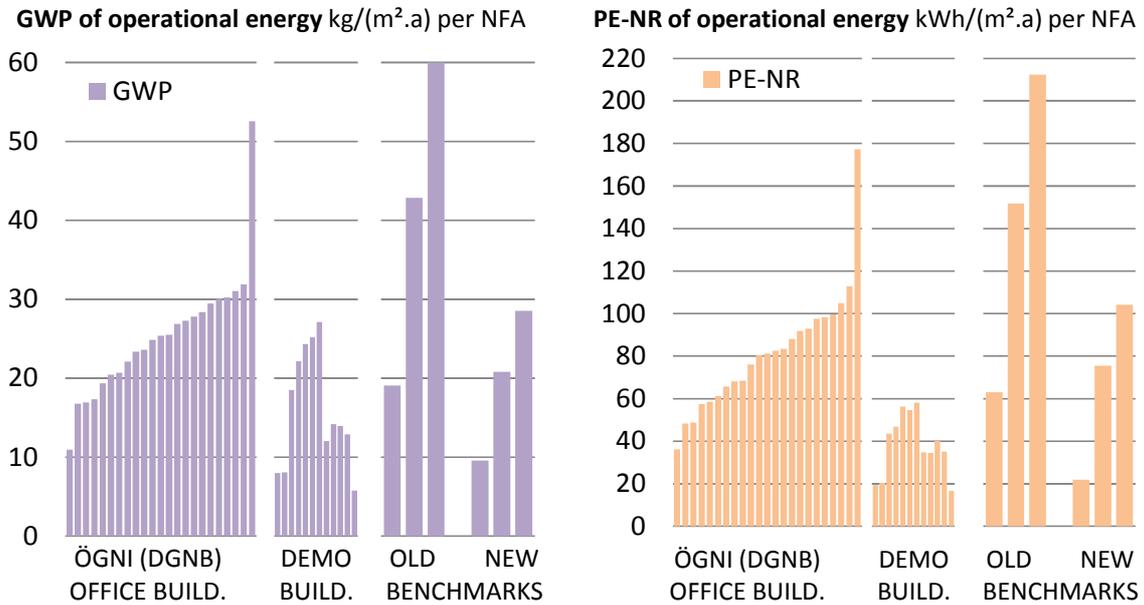


Fig 4: Global warming potential and non-renewable primary energy demand of DGNB certified office buildings in Austria. Impact of operational energy per net-floor-area. Compared with demonstration buildings and benchmarks: target, reference and limiting values.

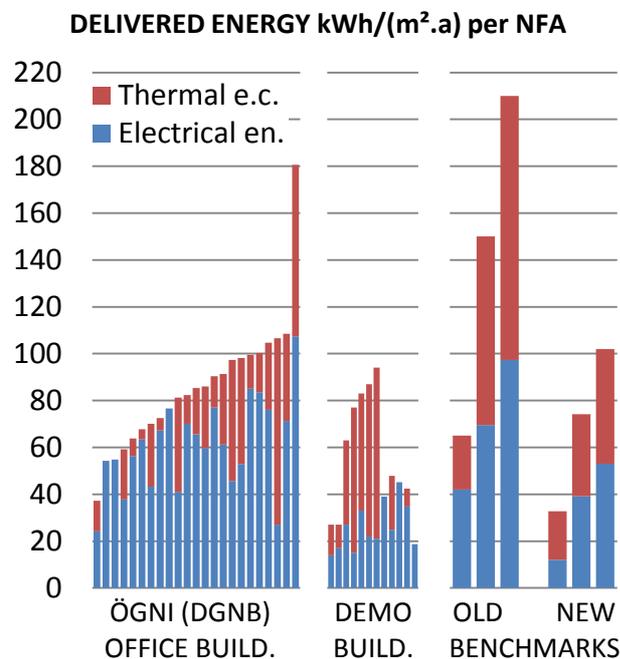


Fig 5: Final energy demand of DGNB certified office buildings in Austria. Delivered electrical energy and energy in fuels and district heating (“thermal energy carriers”) per net-floor-area. Compared with demonstration buildings and benchmarks: target, reference and limiting values.



Conclusions

The early learnings of the DGNB implementation in Austria are the particular strengths of the certification system to raise the awareness on the topic sustainable buildings. Especially with the help of additional certification systems for associations, key players of the Austrian building sector have been involved successfully in the process.

In the first years DGNB was applied in Austria it was easier to reach good ratings for the environmental performance. The recast of the rating system with the proposed adjustment of the benchmarks improves the significance of the results regarding higher energy efficiency and better environmental protection.

The LCA benchmarks of the German DGNB system are based on variable values by means of a reference building model according to the German EnEV 2007/2009. Therefore the LCA criteria cannot be directly applied in other countries with different energy demand calculation. Furthermore the methodology and parameters of the reference building model is criticized for having too few incentives for energy efficient concepts, especially regarding low-tech-concepts or share of window area. For example, a building with a large window area has higher (weaker) benchmarks than the same building with a smaller window area [13]. It is questionable if this methodology delivers the desired results and if alternatively constant target values are more suitable.

For the applicability of the DGNB system to other regions and countries it is recommended that the benchmarks (especially target values) are based on constant values for operational energy appropriate to the building type and to local conditions. Conversion factors for impact indicators have to be determined for all relevant energy carriers to ensure the consistency between benchmarks and audit results. These conversion factors should be adjusted to regional conditions and could also be determined politically as it is done by the Swiss Minergie rating tool.

Further adjustments of the rating system are needed with the aim of evaluating the improved quality of zero and plus energy buildings. This could be achieved by bonus points or additional indicators for load match and grid interaction.

Currently the proposed new LCA benchmarks are under discussion and more case studies will be investigated in order to check and adjust the values.

Acknowledgement

We would like to thank the Austrian Sustainable Building Council ÖGNI for the good cooperation and providing the data sample for this investigation.



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Life Cycle Based Optimization of Building Design

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Abstract: *The goal of the European Union is to drastically cut its domestic greenhouse gas emissions by 2050. Since the building sector has been identified as one of the key sectors for cost-efficient savings, here at least 88-91% reduction is necessary to reach these ambitious targets. It is possible to build or retrofit to a high energy standard, but energy saving measures have a 'price' in terms of investment costs, and also in terms of environmental impacts. Low energy solutions designed by architects are not necessarily optimal in this respect, as in case of buildings the number of variables and the optimization space is very large.*

The EnergOpt expert system presented in the paper is based on state-of-the-art evolutionary algorithms that can automatically find the quasi-optimum solution for new or retrofit designs in a short time frame. The system is able to minimize the life cycle costs or the life cycle environmental impacts of a building. A comparison with an engineer's solution shows the advantages and the potential applications.

Keywords, retrofit, building, optimization, evolutionary algorithm, life cycle cost

Introduction

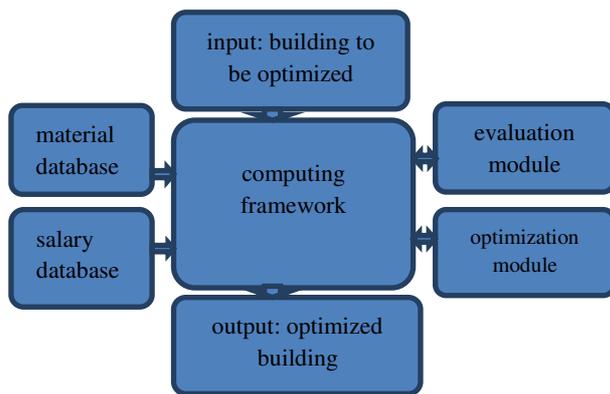
Buildings, responsible for about 40% of the energy use in the European Union, have been identified as one of the key sectors for cost-efficient energy and carbon reduction. The European and national regulatory framework require the increase of building's energy performance with the goal of introducing nearly zero-energy standard for new buildings after 2020. Theoretically it is also possible to reach a net zero or even energy positive level, as demonstrated by built examples. However, investment cost usually sets a constraint on the reduction of energy, and high energy performance must be achieved at a reasonable cost. The available resources are limited, which means that they should be exploited in the most efficient, i.e. optimal manner. The problem is that the design space is very large even in case of smaller buildings. Solutions found by an engineer's approach may be quite suboptimal: the energy saving achieved may be significantly less than the technically possible limit. Consequently, part of the budget is potentially wasted, while a considerable fraction of the energy saving measures becomes locked into the building for decades. Computational methods have been introduced to tackle such large dimensional problems. A comprehensive review by Evins [1] showed a clear increase in the research on the computational optimization of buildings over the last decade. Most of these works apply heuristic algorithms for single or

multi-objective optimization, with the key fields being envelope design, building systems, renewable energy generation and holistic approaches covering several areas.

The EnerGOpt expert system is a relatively new initiative in the field, employing a state-of-the-art bacterial evolutionary algorithm for single- and full Pareto multi-objective optimization. The short time scale makes it suitable to assist engineers and architects to determine the optimal retrofit strategy of a particular building. The system and the underlying mathematical framework have been presented in detail in previous papers [2-4]. After a brief introduction to the system, this paper presents the newly developed life cycle evaluation module. Finally, the performance of a human engineer is compared to the EnerGOpt automatic optimization for a case study building.

The EnerGOpt expert system

The expert system EnerGOpt incorporates state-of-the-art optimization methods superior to



most technologies applied so far in this context. EnerGOpt has a modular structure (Fig. 1).

Figure 1: Structure of the EnerGOpt expert system

The underlying material and salary databases contain the relevant material properties, the cost of the materials and the salaries based on norms, manufacturer data and a Hungarian cost database [2]. The database contains not only the price of insulation materials, but also the supplementary materials, e.g. plaster, fixing, scaffolding etc. The evaluation module calculates the energy performance of the building, at the present version according to the Hungarian official, seasonal quasi-steady-state calculation method. The optimization module is based on a novel bacterial evolutionary method [4] well suited to the specific problem formulation in the renovation sector. The basic data of the building must be entered in the computing framework, as required by the evaluation module. The output is a set of optimized parameters describing the optimal state of the retrofit design. The advantage of this modular structure is that any module can be changed or improved without affecting the other modules, as long as the communication interfaces are not changed. For example, dynamic simulation could be integrated to the evaluation module, however, this would considerably increase the length of the calculations. The objective function of the optimization can be the specific heat

loss coefficient of the building, the heating energy use or cost, and in the latest version the life cycle cost or a chosen life cycle environmental impact assessment category.

Life cycle module

The life cycle module calculates the global cost and the life cycle environmental impacts. The global cost according to the European Directive 244/2012/EU [5] is:

$$C_g(\tau) = C_I + \sum_j \left[\sum_{i=1}^{\tau} (C_{a,i}(j) \times R_d(i)) - V_{f,\tau}(j) \right] \quad (1)$$

where:

$C_g(\tau)$ is global cost (referred to starting year τ_0) over the calculation period;

τ is the calculation period;

C_I is the initial investment costs for measure or set of measures j ;

$C_{a,i}(j)$ is the annual cost during year i for measure or set of measures j ;

$V_{f,\tau}(j)$ is the residual value of measure or set of measures j at the end of the calculation period (discounted to the starting year τ_0),

$R_d(i)$ is the discount factor for year i based on discount rate r to be calculated.

For building retrofit, the investment cost of the retrofit measures and the sum of the annual space heating energy costs during the calculation period was considered, discounted to the starting year. The average expected lifetime of additional insulation and windows is around 30 years, hence for these measures no residual value was taken into account. HVAC systems typically have a shorter lifetime of around 20 years, so the cost of replacements and the residual value must be included. The following parameters are defined by the user, the default values are:

- calculation period: 30 years, as defined for residential buildings in [5];
- discount rate: for Hungary 3 or 5%;
- long-term energy price escalation: for Hungary two scenarios: 2.8% or 4.3% for gas, and 2 or 5% for electricity.

The life cycle environmental impacts are calculated based on life cycle assessment with the principles being similar to life cycle costing, but without taking into account the effect of discounting (this possibility was however discussed by [6]).

$$EI_T(\tau) = EI_C + \sum_{i=1}^{\tau} EI_O + EI_M + EI_D \quad (2)$$

where:

$EI_T(\tau)$ is the total environmental impact over the calculation period;

τ is the calculation period;

EI_C is the initial environmental impacts caused by construction;

EI_O is the annual environmental impact caused by operation;

EI_M is the environmental impact caused by maintenance and replacements;

EI_D is the environmental impact caused by the final disposal/utilization;

For calculating the environmental impacts caused by construction, the built-in weight is linked to the inventory database. Additional impacts caused by transport of materials and execution are also considered. The periodic replacement is calculated based on the expected life span of the elements. The energy demand, determined by the energy evaluation module is also linked to the inventory database. The end-of-life impacts are also included where relevant. The underlying database is the ecoinvent v2.0. Swiss database, which has been adapted to the Hungarian conditions. This database contains the environmental impacts of products considering all upstream processes. All impact assessment category results can be calculated that are included in the ecoinvent database, e.g. global warming potential, acidification etc. The calculation period can be defined by the user, for buildings a period of 50 years is usually taken into account.

Engineering optimization vs. EnerGOpt

The selected case study building is a two-storey single-family dwelling, located in Felsőgöd, near Budapest, the capital of Hungary (Fig. 2). Hungary has a continental European climate with warm, dry summers and fairly cold winters. The average heating degree hours are 72 000 Kh/yr for a base temperature of 12 °C and an internal temperature of 20 °C.

The building was built in 1974 with an unheated basement and a heated attic, and an extension with a partial basement and a heated attic was added in 1992. The total heated net floor area is 260 m². Most of the building elements do not comply with regulations. The ‘old’ part is heated with a solid fuel burner located in the cellar, supplied with wood. The ‘new’ part has a non-modulating atmospheric gas burner, and the heat emitters are radiators in both parts. The primary energy demand for space heating is 189 kWh/m²yr.

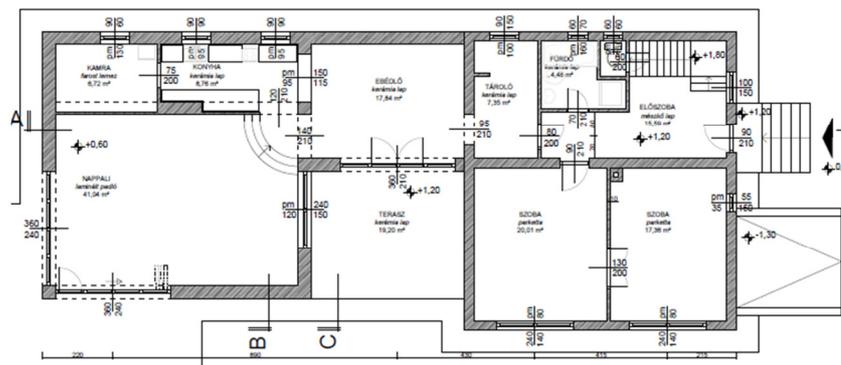


Figure 2. Photo and ground floor plan of the case study building (source: Eszter Váraljai)

There are 14 types of opaque elements (variable: type and thickness of insulation) and 23 types of openings defined for the case study building; hence the problem is equivalent with finding the optimal solution in a 51 dimensional search space. The ‘competition’ between the engineer and the EnerGOpt system was run under identical conditions:

- the energetic status of the original building was evaluated using the energetic evaluation module of EnerGOpt;
- the objective function was the global cost for 30 years;
- the total investment budget was between 2 and 6 Million HUF;
- the same material, salary and energy price database was used, i.e. the engineer could only select from the available components and the same supplementary materials were considered;
- only the building envelope was changed, the heating system remained the original.

The engineer was in this case an MSc engineer student, who was allowed to spend one month for the design of the retrofit. EnerGOpt performed one optimization in less than 3 minutes on a laptop equipped with Windows 7 operating system and an Intel core i5-450M CPU working at 2.4 GHz clock speed, and about 2 hours for scanning the total budget range.

The engineer followed a strategy where she selected the elements responsible for the highest heat losses, and then optimized the additional insulation thickness of these elements one by one based on the global cost of the retrofit. Finally she combined these ‘optimum’ measures into four retrofit packages, and calculated the achieved energy saving, total investment costs and total global cost.

Results

The global cost of the building without retrofit was 19.17 M HUF (1 EUR ≈ 300 HUF). EnerGOpt found the minimum of the global cost-investment cost curve, which can be regarded as the optimum, at around 13.55 M HUF at a budget of 4.3 M HUF (*Fig. 3.*). After this point the global costs started to increase, which means that further investments were not justifiable.

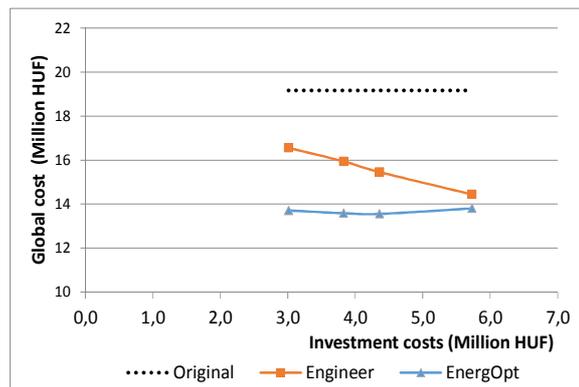
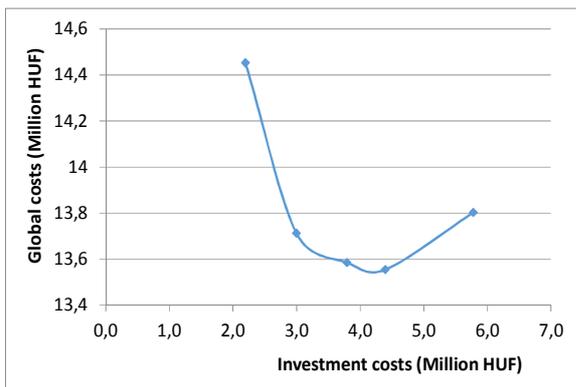


Figure 3 and 4: EnerGOpt results and comparison of EnerGOpt and engineer

The engineer achieved significantly lower savings than EnerGOpt for an investment cost of 3-5 M, but nearly approached it for a higher investment cost of 5.7M HUF (*Fig. 4.*). However, this point is already beyond the optimal budget.

The efficiency of the engineer’s solution can be evaluated as the ratio of the achieved savings and the conditional saving potential, which is the saving achieved by EnerGOpt for a certain

budget [2]. The closer the efficiency to unity, the better the human performance is. On the other hand, the lock-in-ratio expresses the relative amount of saving that is locked into the building due to sub-optimal nature of the retrofit designed by the human expert. The closer the lock-in ratio to unity, the worst the quality of the retrofit is. The efficiency of the engineer was 52% for an investment cost of 3M HUF, but increased to 88% when the budget increased to 5.7M HUF (*Table 1*). Even for the best retrofit package of the engineer, the lock-in ratio was 12%, corresponding to nearly 640,000 HUF in global costs.

The maximum saving potential of the building, as determined by EnerGOpt, is 5.6 M HUF. Comparing this to the lowest global cost achieved by the engineer results in an overall engineer's efficiency of 84%.

Table 1: Comparison of the results of the engineer and the expert system

	v1	v2	v3	v4	overall
Global costs, original (HUF)	19 168 888	19 168 888	19 168 888	19 168 888	19 168 888
Investment costs (HUF)	3 009 911	3 825 725	4 358 869	5 729 940	
Conditional saving potential (HUF)	5 457 090	5 583 998	5 615 400	5 366 571	5 615 400
Saving by engineer (HUF)	2 609 300	3 226 651	3 711 897	4 729 316	4 729 316
Efficiency of engineer (%)	48%	58%	66%	88%	84%
Locked-in potential of engineer (%)	52%	42%	34%	12%	16%

According to the results, the EnerGOpt system succeeded by a large amount, but the test also highlighted some practical problems related to the automatic results.

- The expert system applied windows by different manufacturers, which is unlikely in a real life situation.
- The system chose a different insulation thickness for the ground floor and the top floor walls above each other, which is questionable from aesthetic and functional aspects.
- The system did not consider such functional limitations, as the maximum applicable insulation thickness on a terrace roof or the required fire protection class of a certain element or the opening mechanism of a window.
- The importance of database quality was also demonstrated. The system cannot recognise obviously wrong datasets in a database, which are easily identified by human experts.

The optimization module is currently being developed to take into consideration these practical and functional aspects.

Conclusions

The EnerGOpt expert system is a state-of-the-art research tool supporting architects in the exploitation of the available financial resources at their highest extent. It is a fully automatic system, always finding a quasi-optimal solution with practically zero-lock-in potential in a few minutes for a building of average complexity. For an architect or engineer, it may take several days to calculate the achievable savings for different renovation budget limitations. Another advantage of the systems is that it is able to determine the saving potential of a



particular building, and find the corresponding optimal budget that should be spent on the refurbishment.

The case study in this paper demonstrated that EnergyOpt designed a retrofit resulting in a significantly lower global cost than the engineer. When many measures were combined, the engineer could also realise a significant saving. It must be noted, however, that a practicing engineer would not have the time to carry out such a rigorous investigation of the effect of certain measures. Hence in a real life situation, the efficiency of the engineer's design is likely to be lower than in this case.

As the retrofit of a building is influenced by many factors beyond energy efficiency, such an automatic system cannot replace the work of the engineer, but can assist the design process by delivering quick and reliable quasi-optimal solutions for a defined objective function.

Acknowledgements

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Identification of building materials influence on robustness and uncertainty of multi-residential buildings LCA

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Abstract: *Studies on buildings' environmental performance currently highlight the problem related to the robustness and reliability of LCA. Calculation of building LCA conveys uncertainties due to: calculation model, data used into calculation and LCA user's level of practice. This study only concerns by the uncertainties related to the data used for calculation. The aim of this study is to identify the building materials and elements which have the highest influence on the environmental performance of multi-residential buildings and those having the highest contribution to the uncertainties. A statistical method is used and applied to 10 buildings projects with different structure typologies and different location in France. Four different groups of building materials and elements are identified depending on the sensitivity and uncertainty they have. This study can be useful for the stakeholders, on showing the key parameters on which they must pay attention during the designing phase of a project.*

Keywords: *LCA, building, uncertainties, contribution analysis.*

1. Introduction

The construction industry has one of the largest share on Greenhouse Gas emissions and natural resources consumption Urgent changes are then required relating the energy saving, production and application of materials, use of renewable resources and to reuse, recycling of building materials and minimisation of GHG emissions [1]. For doing so it is important to identify and then improve the part of construction industry which is responsible of these negative impacts. Life Cycle Assessment (LCA) tool is the appropriate way developed and validated by scientific community for assessing the environmental impacts of building [2, 3] eventhough, the recent scientific researches highlight the problem related to the reliability and the robustness of LCA results. Calculation of building LCA conveys uncertainties due to: calculation model, data used into calculation and LCA user's level of practice. This study only concerns by the uncertainties related to the data used for calculation. In building sector treatment of uncertainty is more complex than the other industrial sectors due to the long

service life of building, which makes this sector unique in comparison to other complex products. The uncertainties in building LCA database can arise due to: the service life of building materials and elements that can be lower than the building itself; the properties of materials and elements; as the building project is multi-stakeholders this induce very modifications along the construction phase and the exact amount of materials used will be uncertain parametre; uncertainties in the environmental product declaration (EPD) are also controlled by the same type of uncertainties than for other industrial sectors: environmental database quality, technological variation between materials' production plant, distance of transportation, different methods used for the demolition of materials etc., [4]. Due to these uncertainties and variability of database the results of LCA of building are not robust and reliable. In order to minimise the uncertainties in the database used for the calculation we need first to quantify the uncertainties and variability of data used for calculation and then identifying the biggest contributors in the uncertainty of LCA results [5]. The key purpose of our study is the identification of key data and assumptions that have the highest influence on the result. The methodology used is based on a statistical method and includes both sensitivity and uncertainty analysis. Actually, a parameter which has a small uncertainty but large sensitivity may be just important as a parameter with larger sensitivity but smaller uncertainty (figure 1).

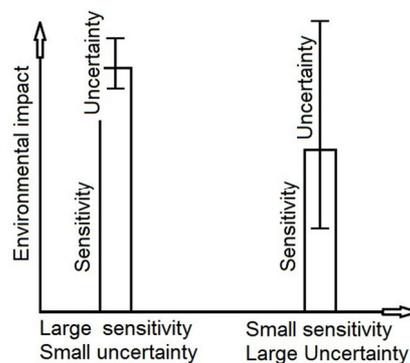


Fig1: The difference between an input with large sensitivity but small uncertainty and an input with small sensitivity but large uncertainty

Based on the relative contribution of the environmental impacts of materials to the environmental impacts of buildings (sensitivity analysis) and the relative contributions of the uncertainties of environmental impacts of materials to the uncertainties of the environmental impacts of buildings (uncertainty analysis) we have identified four different groups:

- Group 1: building materials and elements that have a small contribution to the environmental performances of buildings (small sensitivity) and a small contribution to the uncertainties of these performances (small uncertainty);
- Group 2: building materials and elements that have a small contribution to the environmental performances of buildings (small sensitivity) but a great contribution to the uncertainties of these performances (large uncertainty);

- Group 3: building materials and elements that have a great contribution to the environmental performances of buildings (large sensitivity) but a small contribution to the uncertainties of these performances (small uncertainty);
- Group 4: building materials and elements that have a great contribution to the environmental performances of buildings (large sensitivity) and a great contribution to the uncertainties of these performances (large uncertainty).

In figure 2 we have summarize the four different groups of building materials and elements.

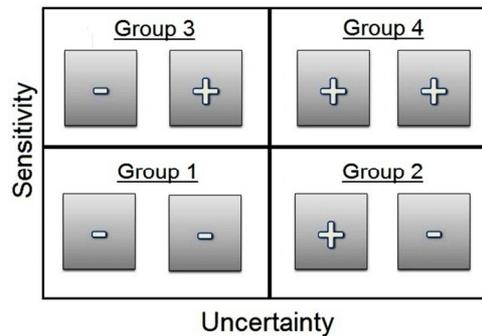


Fig2: The four groups identified in function of sensitivity and uncertainty (“+” indicate ‘large’, and “-“ indicate “small”)

The description of the methodology is presented in the next section, but further details can be found in [6]. Once the methodology is described it is applied in 10 projects of multi-residential building.

2. Method

After the European standards EN-15978 [3] environmental performance of buildings can be presented as a sum of the environmental performance of its building material plus the energy and water consumed during the use phase. In the present paper, we only consider the building materials used during the life cycle of the building.

A possible solution in the identification of inputs parameters that contribute most in the reliability and the robustness of impacts results is by performing contribution analysis. This consists in the combination of the sensitivity and uncertainty analysis. The sensitivity analysis is used for the identification of input variables that have most contribution on the output result. The uncertainty analysis is used for the identification of the inputs variables that most influence in the uncertainties of the output.

2.1.Sensitivity

After Hoxha et al, [6] sensitivity analysis applied in the LCA of building models conducts in the calculation of the following sensitivity coefficients:

$$S(I_{f,i}) = \frac{I_{f,i}^0}{I_f^0} \quad (1)$$

where: $I_{f,i}$ is the nominal value of environmental impact f of material i calculated by the nominal value of mass, impact coefficient and number of use of material during the service life of building. As the nominal value we have consider the mean values, and I_f^0 the environmental impacts f of building.

Parallel to sensitivity analysis we have to perform and the uncertainty analysis.

2.2. Uncertainty

The contribution of environmental impact of material's uncertainties in the environmental impact of building's uncertainties is calculated by the coefficients:

$$RC(I_{f,i}) = \frac{\text{var}(I_{f,i})}{\text{var}(I_f)} \times 100 \quad (2)$$

where: $\text{var}(I_f)$ is the variance of environmental impact f of building and $\text{var}(I_{f,i})$ is the variance of environmental impact f of material i .

In the next section the methodology is applied in 10 multi-residential building located in France.

3. Studied objects

In this study we have modelled 10 multi-residential buildings LCA. The surface of buildings varies between 864 m² and 56454m² and represent about 546654m² living area. The buildings are situated in different places in France. All building have a reinforcing concrete structure, but 9 of them have been constructed with reinforcing concrete walls, and only one has been constructed with cinder block wall. The representative of this sample of buildings in France is very recent. After a recent study of Cerqual in 2012 has been remarked that 74% of buildings build in France have a reinforcing concrete structure walls and 10% have cinder block wall [7]. So our samples of building represent about 84% of buildings build in France.

4. Database

For assessing the environmental impact of buildings we have used French environmental products declaration (EPD) available in INIES database [8]. The uncertaineis due to these inputs variables comes from the fact that for the same material or elements there are different EPDs supplied by different producers. In the case where different EPDs were available, the mean and standard deviation is calculated, and in the case where only one EPD was available, it isn't consider any types of variability.



The mean for the mass of material is considered that defined in the project and the standard deviation is calculated using a ratio for the coefficient of variation equal to 12% [9] that corresponds approximately $\pm 30\%$ of uncertainty about the mean value. The mean and standard deviation for the number of use of material during the service life of building are calculated using different references available in [5, 10].

5. Results

The buildings projects are modelised for the global warming potential indicator. The results about the relative contribution of building materials and elements obtained by these modelisations are shown in figure 3.

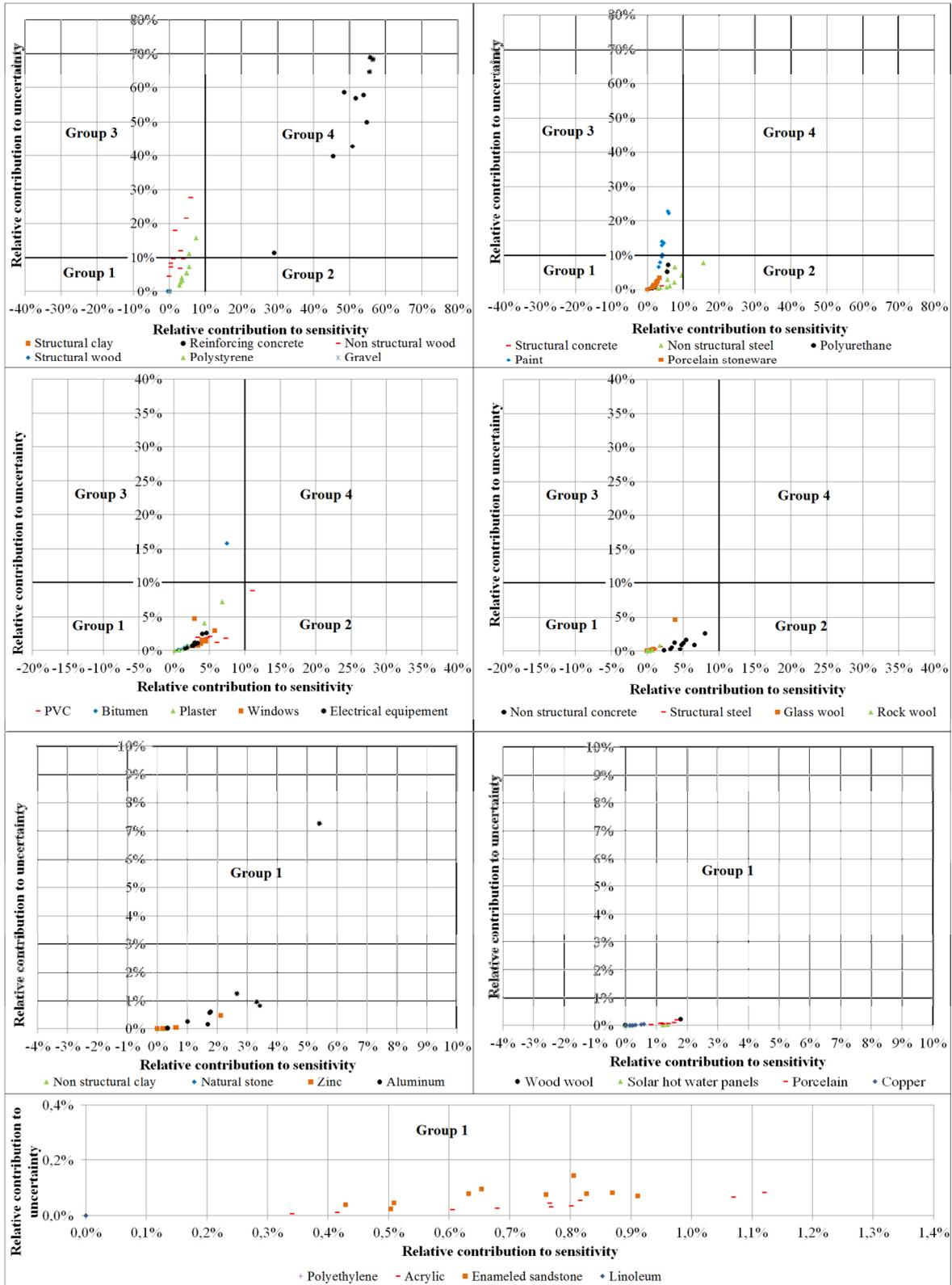


Fig 3: The relative contribution of building materials and elements in GWP sensitivity and uncertainty

6. Discussion

In figure 3 we have presented the results obtained from the modelisation of 10 multi-residential buildings projects. In these modelisation we have consider only the building material and elements without consider the energy and water used during the service life of building. Four different groups are identified for a cut off value of 10%. This can be a discussion point, due to the fact that the classification of materials will change for another value. Also this can be improved, but whatever the cut off value based in these results we note that the reinforcing concrete material has the largest contribution both to the sensitivity and uncertainty of GWP results. But materials such are non structural wood (doors), bitumen, polystyrene and paint have a large contribution to the uncertainty of GWP results but a small contribution to the sensitivity.

A very important point of discussion in these results is the fact that for 9 projets the reinforcing concrete has a relative contribution in sensitivity between 45% and 55% and relative contribution in uncertainty between 40% to 70% and only one has a relative contribution in sensitivity of 29% and relative contribution to uncertainty of 11%. This can be explained by the fact that 9 projets have reinforcing concrete walls and only one has cinder block walls.

7. Conclusion and perspectives

In this study we have presented the results obtained by 10 buildings LCAs, with the aim of identification the building materials or elements having the biggest contribution to the environmental impacts results and the building materials or elements having the biggest contribution to the uncertainty of the environmental impacts results. Doing so we have applied the method based in Taylor series expansion that was easy to be implemend and doesn't required time. By this study we identified the reinforcing concrete as the building material having the greatest contribution to the environmental impacts results and as the greatest contributor to the uncertainty of these results for the GWP indicator. Equally a very important result is the fact of identification of non structural wood, paint and bitumen as the material with a low contribution to the GWP results but greatest contributor to the uncertainty of these results. These results conveys to two important conclusions:

The stakeholders should pay attention in the uncertainty of the non structural wood, paint and bitumen. Paying attention for these building materials and elements will conduct in reliable and robust GWP results.

Urgent researches are needed in the technological innovations for the construction industry, for the improvement of solution with best environmental performances compared to the traditional with reinforcing concrete.



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Session 89:

Neighborhoods with roots. Which are the keys to manage high-complexity and low-resource frameworks?

Chairperson:

Gomes, Vanesa

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Cohousing and the Development of Rating Tools for Sustainable Living in Thailand

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Abstract: *Since 2009 the National Housing Authority (NHA) of Thailand has initiated a new scheme of housing development entitled “PARSUKE Cohousing” in order to create a sustainable community for low to moderate income people. The pilot project focused on participatory process to achieve social sustainability. However, lessons learned from the project prove that making sustainable community requires all three entities of sustainable development (economic, social and environmental) to be integrated in a coherent and balanced manner. In recent years, Thai Green Building Institute (TGBI) has launched rating tools for green building assessment called ‘Thai’s Rating of Energy and Environmental Sustainability for New Construction and Major Renovation (TREES-NC)’ while NHA has introduced ECOVILLAGE as rating tools particularly for residential buildings. The paper presents the key indicators of both rating tools for residential projects and potential of creating economically, socially and environmentally sustainable cohousing community.*

Cohousing, Sustainable living, Rating tools, TREES, ECOVILLAGE

Background of Sustainable Housing and Rating Tools in Thailand

The concept of sustainable development has been adopted worldwide since Brundtland Report (World Commission on Environment and Development, 1987). By definition, it means “development which meets the needs of the present without compromising the ability of future generations to meet their own needs.” It requires a convergence between the three pillars of economic development, social equity, and environmental protection.

However, building industry which is responsible for at least 40% of energy consumption in most countries is still slow in implementing the sustainability concept. In Thailand, building sector, in particular small business building and housing sector is targeted to reduce energy consumption by 10% by 2030 (Ministry of Energy, 2011). Therefore, it is essential to have push and pull strategies for energy conservation.

In 2010, Thai Green Building Institute (TGBI) was co-founded between the Association of Siamese Architects under Royal Patronage (ASA) and the Engineering Institute of Thailand under H.M. the King’s Patronage to tackle the energy issues in building design by initiating a rating system for Thailand. Thai’s Rating of Energy and Environmental Sustainability (TREES) was proposed later in 2012 but still limited only for assessing new construction and major renovation projects. The assessment criteria were designed for commercial buildings, thus not quite suitable for residential buildings.

For housing sector, sustainability is not merely about energy efficiency. It is also important to provide good quality housing for the well-being of people. The National Housing Authority



(NHA) of Thailand has been developing housing projects for low-income people in Thailand for more than 40 years and found the failure in many projects due to the lack of both environmental and social concerns. In order to solve this problem, two research projects were conducted:

- 1) The Guidelines on Housing Development Project to Achieve Sustainable Development, and
- 2) Criteria and Rating Tools for Assessing Sustainable Communities.

The first project was completed in 2010 paving the way to develop a pilot project entitled 'PARSUKE Cohousing' to create a sustainable community for low to moderate income people, followed by the second one which was completed in 2013 to propose ECOVILLAGE as a rating tool for assessing sustainability of residential projects.

Introduction to Cohousing

Social aspect is one of the key components for sustainable development. Nonetheless, a number of housing projects of both government and private sectors failed to serve the need of their residents socially. Members of housing communities especially in urban areas these days tend to live individually rather than building relationship with others to create communities. They are not only disconnected with their neighbours but also the environment.

“...If urban areas do not provided civilised places for people to live and for communities to prosper then it will not matter how ‘green’ they are, they will not be sustainable.” (Rudin and Falk, 1999)

Cohousing was originated in Denmark during the 1970s and spread throughout Northern Europe during the 80s, the United States, Canada and Australia in the 90s, then Britain, New Zealand and Japan. They are various in forms of dwelling and management and linked to the tradition of communal living. Numbers of dwelling units range from 6 to more than 100 but 20-40 are by average (Meltzer, 2005). In general, cohousing has 6 distinguishing characteristics namely: participatory process; neighbourhood design; common facilities; self-management; absence of hierarchy; and separate incomes (McCamant and Durrett, 1994). PARSUKE Cohousing project was also developed based on such characteristics.

PARSUKE Cohousing Project

The research project entitled “The Guidelines on Housing Development Project to Achieve Sustainable Development” was aimed to develop a housing project which focused mainly on the participation of potential residents since the beginning of the project. 'PARSUKE Cohousing' was then named to promote the project to the public in order to call for potential residents. The acronym represented the concept of the project. It was from 7 individual words: Participation, Affordability, Resource, Society, Unity, Knowledge, and Environment. The pronunciation of 'PARSUKE' in Thai also means 'bringing happiness'.

A site in Rom Glao, Bangkok was selected as it was owned by NHA and close to other NHA’s housing projects. There were parks, schools, banks, markets and other amenities. Therefore, it was considered a previously developed land which met a criterion for sustainable site according to TREES (TGBI, 2012).

By considering that the idea of cohousing was new in Thailand and it was for a niche market, the potential residents were explained to gain ideas about cohousing through various forms of communication, e.g., poster, brochure, booklet, road show and open house event, website, and workshop as shown in Figure 1.



Figure 1 Poster and brochure of PARSUKE Cohousing project

Unlike most housing projects available in the market, PARSUKE Cohousing did not give pictures of the final look of its individual houses and housing community for selling purpose. The open-ended design required community members to participate in, share ideas, and make decision for what they wanted together. The project was planned for 3 phases: pre-occupancy or planning, design and construction, and post occupancy. The pre-occupancy or planning process involved selection of community members which was essential for shaping the community in the future. The design and construction process involved participatory design for single dwelling units and community. It was collaboration among potential residents, architects as well as support organisations including power and water supply providers, and contractors. The post occupancy process involved self-management and maintenance of environment or sustainable community. However, the scope of research was limited to the planning and design process only. Building construction and community management were to be proceeded by NHA after the first phase.

Data collection was conducted sequentially based on the project phases. When advertising the project, there were 141 participants giving information on questionnaires. Besides personal data, they were asked to give answers on requirements for dwelling units and housing community such as reasons to join the program, preferable housing type and shared facilities, range of affordable prices, incentives, and expectations from PARSUKE Cohousing in terms

of economic, social and environmental sustainability. After the selection for the first group of potential residents, there were 10 families for 10 plots of sub-divided land. The ten families participated in a series of 6 workshops to collaboratively develop the design of own units and the whole community with the team of architects and researchers. The project activities are presented in Figure 2.



Figure 2 A series of design workshop

Results showed that 86% of participants in the studied area preferred detached house over townhouse (8%), condominium (3%), and others. The reasons to join the program were mainly location (23%), participatory design process (19%), the characteristic of sharing community (19%) and getting the house designed by architect (17%). The preferable incentives were special loan program (60%), saving program (34%), employee welfare program (5%), and property tax waiver (1%). With the group of selected families, required support facilities were library (40%), motorcycle (30%), recreation room (20%), club (20%), laundry (10%) and park (10%). For outdoor spaces, both playground and garden ranked the first (70%) followed by sport area (40%), community store (30%), swimming pool (20%) and child care unit (10%).

In terms of environmental concern, the participants required wastewater management (70%) as the first priority followed by solar energy, waste management, and transportation at the same rank (60%), edible green fence (20%) and pond (10%), accordingly. Sixty percent of the participants preferred energy saving in every part of building while 30% wanted only in some parts if necessary and 10% left their decision up to suggestions from experts.

Based on the results and recommendations, there exists an interest in cohousing project but all participants require more knowledge, understanding, collaboration, and time to develop such project when compared to the 'ready-made' ones that are conventional. It is crucial to invite government, stakeholders, and support organizations to engage in the project. Promotion schemes and incentives should be proposed to overcome all financial constraints since the beginning of the project. It is suggested that cohousing could be welfare housing for employees with similar lifestyles and schedules (Takkanon et al., 2010). Design for

environmental sustainability especially for the housing projects in hot-humid climates is considered an important issue regardless of level of income. It needs further studies and rating tools for assessing sustainability of the projects should also be developed with regards to the unique characteristics of residential design.

TREES-NC

Following LEED as an example, TREES-NC was introduced in 2012 to assess new buildings and those with major renovation such as installing new building envelope or changing air-conditioning system of the whole building. The TREES-NC rating system is made of a combination of 8 credit categories: Building Management (BM), Site and Landscape (SL), Water Conservation (WC), Energy and Atmosphere (EA), Materials and Resources (MR), Indoor Environmental Quality (IE), Environmental Protection (EP), and Green Innovation (GI).

To receive TREES-NC certification, 9 prerequisites and credits are required. Out of total 85 points, weighting credits of each category are presented in points and percentage as shown in Figure 3. There are four levels of certification determined by points that the project earns: Platinum (61 points and above), Gold (46-60 points), Silver (38-45 points) and Certified (31-37 points).

The assessment is considered appropriate for some building types including office, hospital, hotel, and school, etc. Since most indicators are for buildings with environmental control systems, the assessment could have a bias against passive design which is prominent in a number of residential projects. Housing projects or other types of residential buildings which partly rely on natural ventilation therefore inevitably fall into this category. Hence, there should be a new rating system group to address the particular needs of residential project types to earn credits either for TREES or other certifications.

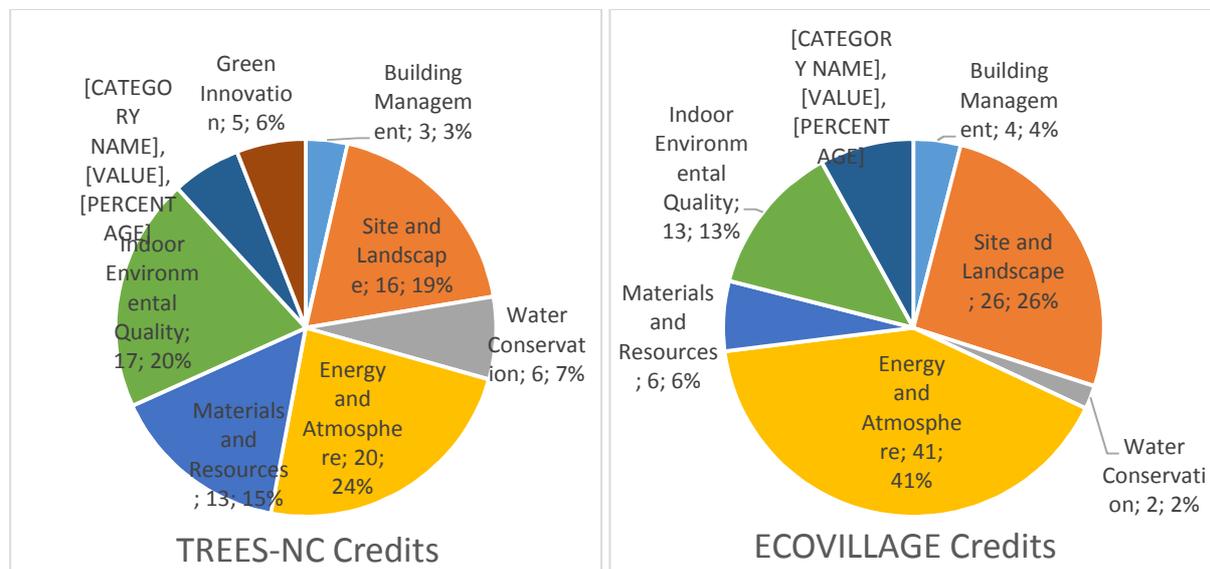


Figure 3 TREES-NC Credits VS ECOVILLAGE Credits



ECOVILLAGE

As a governmental authority, NHA had a mission to develop an Eco Village based on self-sufficiency philosophy in order to achieve sustainable development. The project took into account how to design with environmentally friendly materials, innovation for energy savings, waste reduction, and promoting green community and social enterprise (Sreshthaputra, 2013).

Since there were not proper rating tools for residential projects in 2012, NHA took a lead by developing ECOVILLAGE rating system focusing on two types of residential projects:

- horizontal buildings with 9-metre height limit e.g. detached house, duplex house, row house and shophouse, and
- vertical buildings which are taller than 9 meters. The building types include shophouse, flat, and condominium.

Both types have the same credit categories but differ in weighting credits. However, ECOVILLAGE was developed in accordance with TREES. In order to make it simpler for residential buildings, there are only 4 credit categories and the points for each category are specified as follows: Site and Landscape (25 points), Building Design (50 points), M & E Systems (15 points), and Management (10 points). For this rating system, prerequisites are not required.

Comparison between TREES-NC and ECOVILLAGE

To compare ECOVILLAGE with TREES-NC, the weighting credits according to TREES-NC categories are as shown in Figure 3. The credits of both systems can then be compared in percentage as shown in Table 1. Since the ‘Green Innovation’ category is not specified in ECOVILLAGE rating system, it is excluded in TREES-NC for comparison.

Table 1 Comparison of ECOVILLAGE and TREES-NC credits in each category

	BM	SL	WC	EA	MR	IE	EP	Total (%)
ECOVILLAGE	4	26	2.5	40.5	6	13	8	100
TREES-NC	3.75	20	7.5	25	16.25	21.25	6.25	100

The figures show that ECOVILLAGE emphasises more on Site and Landscape, Energy and Atmosphere, and Environmental Protection categories when compared with TREES-NC. The results can be analysed that the former rating system is designed for housing projects of which site location and planning are very important while the latter is mainly for commercial buildings with site limitation especially in urban areas.

Energy and Atmosphere category always has the largest number of points in both systems but it is very important in case of ECOVILLAGE for housing community. It is found that about



60% of energy used in a two-story house in Thailand are for air-conditioning system while for other building types such as shopping mall, hotel, and hospital, lighting and other building systems share their parts. Passive design strategies especially for hot-humid climates including building envelope design, design for natural lighting and natural ventilation, and shading design are the integral part of Building Design category as defined in ECOVILLAGE. Since the range of green materials for commercial projects is wider than that for housing projects, TREES-NC gives far more credits to Materials and Resources category.

In conclusion, housing projects are facing the challenge of achieving social and environmental sustainability. For social dimension, cohousing is an attempt to create sustainable community by using participatory process as a key to build relationship among community members. However, cohousing project shows the need of design for energy and resource efficiency. Environmental dimension calls for design that serves its occupants' needs and has low negative impacts on the environment. Even though there is still no single rating tool to comprehensively assess all elements of sustainability one project can achieve, TREES and ECOVILLAGE have been developed to assess environmental sustainability. ECOVILLAGE is designed for assessing residential projects in particular. It addresses the unique characteristics of passive design for tropical climates. This rating tool and its credit system can be revised and developed further after its application on housing projects to assess their sustainability.

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Fatimid Cairo: a Sustainable Neighborhood from Medieval Times

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Abstract: *Islamic cities (especially Fatimid Cairo) have emerged as a unique urban model embodies distinctive sustainable characteristics reflecting Islamic culture values. This model remained successful and evolving steadily for nearly ten centuries since the end of the tenth century (969A.D) depending on the strength of its aspects. The community itself lived the socio-economical and environmental concept of sustainability and applied it on its urban structure which revealed its social cohesion, economical integration and environmental compatibility in the region. This paper aims to analyze Fatimid Cairo urban structure to reveal its sustainability characteristics, which made it an outstanding universal value (according to the criteria of inscription). This study relies on an historical, analytical and deduction methodology of urban structure; to demonstrate interrelationships between social, economical and environmental sustainability characteristics and the built environment. Such characteristics which formed urbanisation of Fatimid Cairo and gives it its quality of life, could form a strong base for building a futuristic sustainable urban model in Egypt.*

Keywords: *Sustainability characteristics – Fatimid Cairo – Islamic Urban Form – Quality of Life – Self-Sustainability.*

What sustainability means for Fatimid Cairo

The concept of sustainability is hard to generalize. Each region or community has its sustainability goals that vary according to society cultural characteristics. What we would to expose by sustainability is to focus on neighborhood assets and express values that have been formally adopted by community residents (1).

Evolution and Configuration of Fatimid Cairo (Historical Approach):

Usefulness of the historical approach is, outlining the framework in which the Fatimid Cairo evolved across time and demonstrates its urban configuration changes in place. The Islamic Cairo grew up in the form of several nucleuses out of each other from south to north. Firstly, was Al-Fustat in 641AD, secondly Al-Askar in 751AD, Thereafter Al-Kataea in 868AD (2). By 969 AD the Fatimid Caliph Al-Muizz enters Egypt by

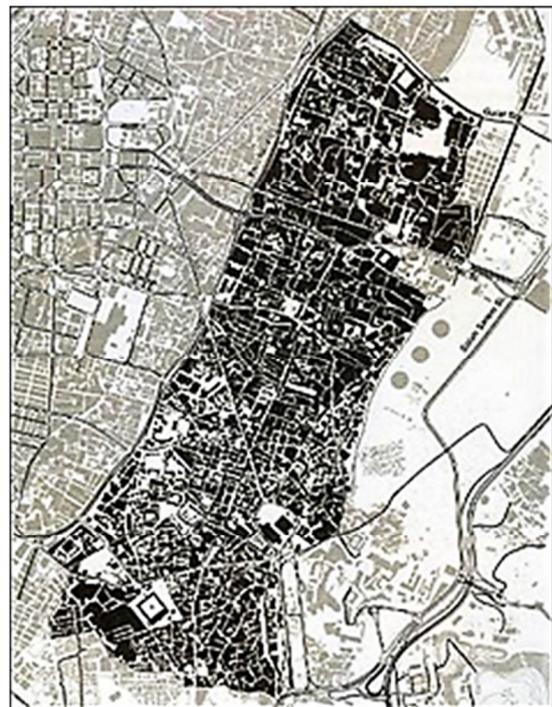


Fig. (1) Fatimid Cairo borders

Jawhar, the general leading of Fatimid forces. He selected a site for the new city which was completed in 971 AD as a princely city for the Fatimid Caliph to be his imperial capital. It was bounded between the Egyptian Gulf in the west and Al-Mokattam plateau edge in the east. The city had originally an area of 340 acres, 60% of which were residential quarters, 30% were royal palaces and their gardens (3).

Fatimid Cairo started as a princely walled city, and transformed into a public city in the Ayubid period. The most rapid transformation took place during the reign of the Bahri Mamluks. Most construction of this period occurred along Al-Qasabah, the main axis of Fatimid Cairo running north to south from Bab Al-Futuh to Bab Zuwayla (4).

Environmental compatibility of Fatimid Cairo:

Environmental compatibility means, dealing properly with the environmental determinants and overcoming constraints. At the urban form level, for achieving the compatibility there are some important issues to address, such as: mixed uses, movement system integration, residential uses and its relation with industry, open spaces and commercial areas. So it is crucial to analyze these urban issues of Fatimid Cairo urban configuration, and show to what extent they are sustainable through their response to the environmental conditions. To a great extent, a good part of the Islamic city is shaped by decisions that aimed to mitigate the climate (5).



Fig. (2) Tortuous alleys of Fatimid Cairo

- **Mixed Uses:** The most distinguishing feature of Fatimid Cairo is the obvious presence of residential neighborhoods surrounding the urban activities which considered as an important principle of urban sustainability. These mixed uses that contain palaces, mosques, hammams, wekalas, shops, and a number of four to five story houses made it vibrant and livable until now (3). The juxtaposition of these activities reflected its interdependence, the integration of functional relationships and the diversity in size and spatial location. This mixed use helped on overcoming of the environmental constraints of the desertic environment.

- **Residential uses:** Regarding the areas' allocation, residential areas of Fatimid Cairo extend on both sides of Al-Qasbah composing homogeneous social groups of the same profession, even though they varied in income levels, where the city did not know the segregation of classes (interdependence). Residential plots reflected a great variety to fit all segments of society (diversity). The urban fabric of Fatimid Cairo is characterized by dense configuration of contiguous enclosures with inward oriented houses helped to decrease the sun-exposed surfaces, and consequently reduce internal temperature.

The concept of causing harm and damage was decisive in determining the location of industries and separating them from residential areas within the city. It didn't authorize the establishment of heavy industries or tanneries except outside the city (6). Jurists considered

extensively the sources of damage such as smoke, odor, sound and vibration. They discuss the sources of damage, their origin, and their necessity to the livelihood of their owners (7).

-Commercial areas: Marketplaces in Fatimid Cairo represent the city spine which extends in a linear axis from north to south, known as Al-Qasabah. These Marketplaces have achieved the environmental sustainability of commercial uses for a long time till now, according to three principles. The first principle, allocating shops with respecting similarity, has achieved the environmental sustainability of Al-Qasabah through its ability to reduce the walking distances through providing diversity of goods and services in a limited place. The second principle, relative frequency of activities to provide needs of certain products, created a functional module for Al-Qasabah, to promote the linear extension and pedestrian movement. The third principle, avoid causing harm and damage, such as smoke or repulsive odors, achieved sustainability by reducing the risk of pollution by smoke and repulsive odors (7).



Fig. (3-4) thoroughfares and secondary street

- Movement System: The Fatimid Cairo extended in a linear form that is always preferred for pedestrian movement. The analysis of urban fabric demonstrates three planning considerations affected the formation of the network, firstly, the commercial markets sites, secondly, grand mosques locations and thirdly, the hierarchy of roads according to movement volume. These considerations led to three types of streets. The main thoroughfares (Al-Qasabah) reserved for commercial and trading activities, grand mosques, public buildings and amenities; they constitute the main arteries of the city ranging between 60 to 70 cubits. Residential uses are distributed on these secondary streets with width ranging from 40 to 20 cubits, they are a public way in which all people have the right of way, they are submissive to Sharia laws and not to be infringed upon, even for building a mosque, and they may be expanded to fulfill the public interest. Thirdly, the cul-de-sac (alley, Zuqaq) is 7 cubits not less than that, which most jurists consider it a private appertaining to its surrounding properties.

This movement system of secondary street and cul-de-sacs (alleys) diverges from Al-Qasabah in appropriate width extend in a dendritic pattern, suitable for man and animals movement and suitable for the climatic conditions (8). The orientation of Al-Qasabah from north to south helped to provide a great amount of shadows and ventilation. The tortuous internal alleys helped to reduce direct exposure to the sun and mitigate the temperature (9).

Open spaces: The urban fabric of a city is composed of three main elements: building blocks, streets and open spaces. These open spaces are classified into public and private. In Islamic cities as well as Fatimid Cairo, the streets and open spaces were intertwining together as a result to environmental and social considerations. While environmental factors helped the Greco-Roman urbanisation to provide open spaces such as (Agora, Forum, and Plaza), the Fatimid Cairo overcame the environmental constraints by providing the private and semi-private open spaces (Interiority), no matter whether you are in the street or inside the mosque or the home, you are in one aspect always on the inside (5). The Fatimid Cairo type of street life (open space) creates social bonds that contribute to a better quality of life. Courtyards are semi-private, open spaces that are reassuring by their human scale and that lend themselves to interactions between residents (10).

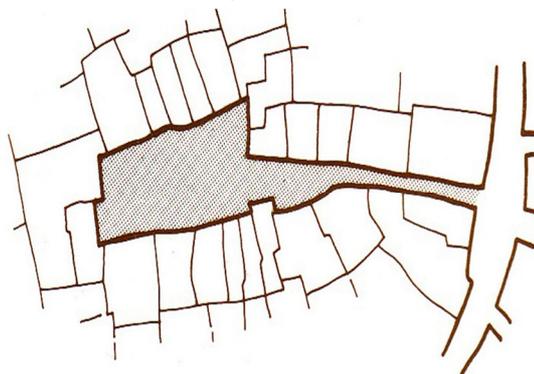


Fig. (5) open spaces diversity

Social cohesion of Fatimid Cairo

Social sustainability considers how individuals, communities and societies live with each other, and societal provisions and expectations for. The interactions between people are the first factor of organization of a city (10). Sustainable communities formed as an open community are equitable, diverse, connected and provide a good quality of life. It includes issues of health equity, education, social equity, livability, social justice, social capital, social responsibility,... in short, and all the different parts that, together, make up a community. One of the major elements of the Islamic social system was the internal organization of the city according to occupational affiliation which gave the community of Fatimid Cairo its social cohesion. There is non-discrimination among the population of Fatimid Cairo on the basis of income, race, social status or religion.

The effect of built environment on the social characteristics

The mosque, alley and house courtyard formed the social relationship inside the configuration of Fatimid Cairo. The Mosque and its surrounding open space represent the largest open area within the urban fabric, as it is located in front of Al-Hakim and Al-Azhar Mosques. These spaces are places for annual worship and community ceremonies. The grand mosque is the weekly meeting place for neighborhood residents, while the mosque of the alley (Al-Harah) is the daily meeting place. So the mosques encourage the social cohesion, strengthen solidarity. A lot of the problems were solving in the mosques by natural leaders and jurists. The alleys are the places of social interactions, either for everyday life or events. The alley (Harah) with its semi-private open space encouraged social life and reinforced safety within the residential areas (privacy). The house courtyard is the main venue for the social life of the family and sometimes contiguous families. The concern for privacy was reflected in the physical form of the city in several ways. Among these are the limits of building heights throughout the city, avoidance (or architectural treatment) of windows on the street, and the

placement of doors within the street (7). Interdependence and Privacy represented basic rules of residential sustainability of Fatimid Cairo.

Public services and social responsibility

The public services (educational, health, religious, social) varied in terms of functions, sizes and distribution within the urban fabric of Fatimid Cairo. The induction of services diversity reveals the desire of both community and rulers to provide the city with various institutions that realize the growth and evolving of community. There are four essential factors contributed in services sustainability of Fatimid Cairo. Firstly, diversity of services and its ability for growth and evolution. Secondly, distribution of services which combines concentration and spreading. Thirdly, spatial and functional development of services has been associated with community lifestyle levels (necessities, needs and Improvements levels). Fourthly, compatibility of control mechanisms (Al-Mohtasseb) led to raise the efficiency of urban management for services.

The system of Hisbah (the supervision of moral behavior within the town) and Al-Mohtasib have an important role in controlling and adjusting the changes in the built environment of Fatimid Cairo to achieve social justice, equality, removing the damage, recognition of rights and encourage the people to achieve the public interests of the city (6). The role of Al-Mohtasib started since the beginning of Islamic city and grew steadily. He was broadly empowered to observe the fairness and honesty of the merchants. He was also responsible for seeing to the punishment of the faulty (3).

Alwaqf (the endowment of property for social services) reflect the role of social responsibility within the Muslim community and its ability to provide services. There were an interest of constructing schools (madrassa, Kutab), Sabil (water source), Tekia (feeding poor) and Pemaristan (hospitals). Urban management in Islamic cities relied largely on endowment foundations voluntarily financed by endower. It performed a significant socio-economic role with regard to the needy. A property donated for the sake of divine reward becomes in legal terms the property of God, and its profit is expended according to the donor's clauses. (11).

There was probably hardly anyone in Islamic cities whose life was not at one stage or another shaped by Al-Waqf system, either in the form of schools or mosques, or in the form of commercial locales, or bathhouses, and other social needs, or in the form of allowances, financial support and provisions (12). Endowment shranked the gap between the rich and the poor as it insured permanent incomes for the deprived persons and thus strengthened the community cohesion. This social welfare policy tackled the problem of poverty and deprivation. Collected funds were spent for the provision of municipal services (potable water, streets pavement, city-wall) and public utilities (education, health, social welfare, worship) at no charge to citizens. The availability of funds and its autonomy in expenditure, made these foundations the backbone of the municipal management in Islamic cities. Ibn Khaldun described Al-Waqf as the "**science support**" and the reason of progress in Islamic cities (13). At the socio-economic level, Al-Waqf played a crucial role in, distributing wealth, reducing poverty rate and promoting social cohesion.



Economical integration of Fatimid Cairo

The issue of economical sustainability is complex and multi-indicators, but our focus here is upon the most two important features characterized Fatimid Cairo economical integration; economical specialisation and economical control. From these two points branchout a lot of indicators. What we address here is, how the economy is directly related to the built environment.

Economical specialisation

The economy of Fatimid Cairo was and still characterized by diversity wich give it sustainability. Different segments of Al-Qasabah reflected specialisation of production and tradingmarketplaces.The marketplaces were following the qualitative division of goods. They were providing the daily needs of residents beside the commercial and industrial busnisses. While a part of the economy dedicated to everyday needsthere was another part was dedicated to the outside community.Fatimid Cairo remained the center of economical life and international trade until 1798 (14).Diversity and specialization leading cause of sustainability of certain activities till now.

The most significant marketplaces along Al-Qasabah were al-Nahassin(copper market), al-Sagha (jewelry market), al-Ghouriya (spices andperfumes market), al-Sorougiya (oil andvegetable market), al- Daggagin (chicken market),al-Fahamin (coal market), and al-Khayamiya (tent market), al-Selah (weapon market),al-Harrareyin (silk market) (15). Some of these markets were performing services for the residents of the neighborhood, while the others were performing services at the city. Juxtaposition of Industry and Trade places and their integration led to economic efficiency. The diversity and multiplicity of markets in terms of size and type helped the continuity and sustainability of activities.

Management and economic control

The Specialisation of markets made it more professional and have its own management which take its responsibility regarding the profession.Once the Fatimid Cairo began to look at the markets as the source of income, administrative machinery had to be created to supervise the markets' organization and to ensure a steady flow of income. This was to be found in the person of the Al-Muhtasib whose main concern was to supervise the quality of merchandise and to ensure that the process of buying and selling within the market followed prescribed religious principles (7).

What is lacking this model to be applicable now:

This unique form of Fatimid Cairo was originated from the Islamic Culture values and the constraints of desertic environment; it remained in progress to achieve the socio-economical and environmental needs of the population for long periods. Since the beginning of the nineteenth century, the influence of this model declined for many reasons and factors. It is important to introduce car movement variable on the Fatimid Cairo model which depending entirely on thepedestrian network. Contemporary urban laws that forming urbanization of Islamic cities (landuse allocation, land subdivion) do not achieve the social cohesion and environmental compatibility as in Fatimid Cairo.While the world is going to encourage



mixed-uses and compact urban fabric there is a lack of community awareness of the importance of this sustainable form.

Results

- Lessons from the design of urban forms can be found in the Islamic city, which were very efficient to protect from hot and dry climate and to use wind to refresh the city at different scales thanks to a compacted urban texture (with the traditional courtyard) which creates a dense but porous and breathing city.
- Urban development of Fatimid Cairo was formed, bearing on the coincidence of knowledges, ideals, power, laws, order, practices, social customs, cultural bearings, and religious views.
- Mixed uses, compacted urban fabric, walkability and open spaces, reveals the originality of Fatimid Cairo urban form and its ability to achieve environmental sustainability.
- Network shape and hierarchy encouraged a heavy movement in some parts (commercial areas) and limited it to minimum in other parts (inside residential alleys), so this shape makes some places liveable and vibrant and others tranquil and safe.
- Compacted urban fabric of Fatimid Cairo reflects the diversity of urban and architectural elements which achieved environmental compatibility, social cohesion and economic integration of the different levels of population.
- Self-sustainability had been achieved in Fatimid Cairo through the non-governmental organizations (NGOs) such as Al-Waqf (endowment) which provided the public services (health, education, worship, social welfare).
- Al-Hisbah played an important role in the management of Fatimid Cairo urban form and control social and economic changes.
- Intelligibility of social and economic identity of Fatimid Cairo reflected clearly on the built environment and its sustainability.
- Small parcels of Fatimid Cairo encouraged human scale buildings, and the territory became more resilient to change.
- The linear formation of Al-Qasaba and distribution of marketplaces and workshops helped to achieve economic integration and to promote competition and prohibited the monopoly.

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Preserving the Old “Ksar” of Bou Saada - Algeria

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Abstract: *This study aims to highlight the built and cultural heritage of the old Ksar in Bou Saada while looking for developing its economic potential. It also intends to contribute to the promotion of cultural tourism activities and improve the quality of life for the local community.*

Historically dating back to the medieval period, the “Nakhla Mosque” is the initial core and a main landmark in the city. Four factors were determinant in the foundation of this holy city: water, security, agriculture and religious spirit. Today, it is crumbling under the rapid urban growth and the weight of a rampant demography; more than eighty thousand inhabitant.

A historical and morphological analysis is used to understand the physical and cultural aspects generating the local environment, as well as the facts behind the sustainable urban development of this secular Saharan town. The expected results lead to identify appropriate regeneration strategies.

Keywords: *Built Heritage, Cultural Heritage, Economic Development, Sustainability, Strategic Planning, Bou Saada.*

Introduction

Historic urban centers are special places not only due to their cultural heritage, but also due to their urban pattern. These old urban fabrics are suffering from squalor. For a long time, this heritage is crumbling under the weight of poverty and absence of rehabilitation works necessary for their maintenance and improvement. These historic centers are losing their traditional character as relevant measures are not taken. There is a need to preserve the heritage of Ksours in the South of Algeria. (see Figure 1)

The Ksar is a human settlement, peculiar to the populations in the Saharan environment. It is also a traditional urban form in the walled cities of this region. Regarding its construction rules, the Ksar in relationship with the palm grove is the most adequate built form for the local climate. The layout follows an organic principle implying various scales of environmental appropriation: building scale (private houses and public amenities), social or familial scale (cluster of houses surrounding the dead end), urban unity scale (buildings along an axis – Zkak - or around a square – Rahba - a separate unit for the group), city or Ksar scale (regarding their structure and hierarchy, the articulated entities lead to the emergence of a center that can be identified and recognized by the community).



*Figure 1: Old urban fabrics are suffering – inside the Ksar.
Source: the authors, 2006.*

Background

Many civilizations settled in Bou Saada and its region: the Romans, Arabs, Turks and French. The first building in the oasis is a Mosque called "Djamaa El Nakhla". It culminates the Ksar that dates back to the medieval period. The demographic growth of the Ksar led to an archetype of the Islamic city. The everyday survival of the residents was determinant for the localization of the Ksar through a water resource (Oued/river) and an ideal crossroad for cultural and economic exchange.

During the Turkish Regency, the spatial structure was composed of Ouled Attig and Achacha quarters. Then, the urban fabric expanded as far as more houses were built in accordance with the population growth of the locality. When the French came in 1848, Ouled Attig tribe was already on the upper part of Bou Saada, while the Mouamine in the lower. Thus, the walls surrounded the Ksar against the new invaders. In 1860, the European quarter "Plateau" was founded next to the Military camp and the "Rahba" became the "Colonel Pein square". It is a typical Saharan city founded in the thirteenth century; it owes its prosperity to its position advantageously chosen in the foothills of Oulad Nail on one of the routes followed by most of the nomads. There used to be a place for a fairly large trade exchange through many Jews and Mozabites. Lush Palm grove, yet situated in a semi arid zone but boasts of torrential flood regime of the Bou Saada River and the slightly magnesia water sources.

As a gateway city, Bou Saada is a marvelous oasis at 250 km south of Algiers along the National Road N8, offering the closest Saharan specimen, complete with palm groves, sand dunes, white koubbas (cupolas) and camels. The Oued (River) Bou Saada, flowing at the foot of a huge cliff before dying in the Chott El Hodna used to sustain palm trees along a three kilometers ribbon, is no longer able to supply all the multifarious activities. Water is often rationed in the city, while the new quarter that has sprung up round the textile factory has further aggravated the problem.

The original village lies in the valley's lowest part; narrow lanes of the smiths ascend to the Djemaa Sidi Brahim, one of the many mosques, from which the view overlooks the whole oasis. Three simple tombs lie under the whitewashed koubba in the middle of an abandoned cemetery; the French painter Etienne Dinet, whose work is represented in the Museum of Algiers, was so impressed by the charming Bou Saada that he lived there for some 40 years after becoming a Muslim.

In the mid twentieth century, Sidi Mohamed Ben Belkacem founded a Zaouïa at El Hamel, thirteen kilometers southwest of Bou Saada on the National Road N46. This Soufi brotherhood soon acquired a great reputation as a center of Islamic studies. The simple but graceful dazzling white koubba is surrounded by six irregular cupolas. (see Figure 2)

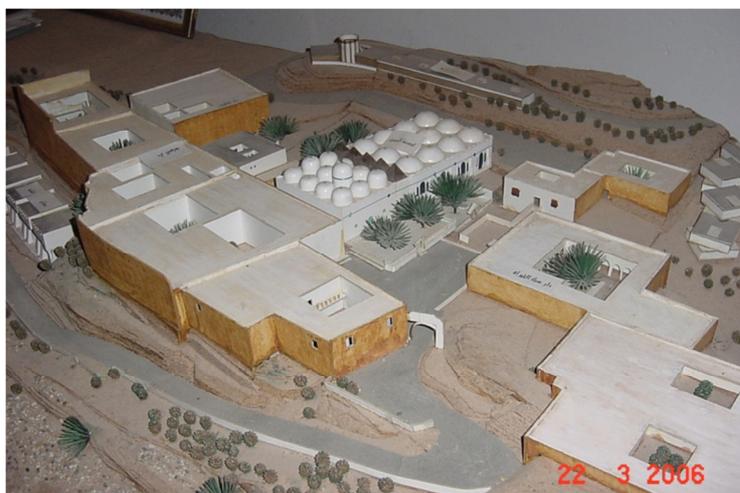


Figure 2: A model of Zaouia el Hamel.
Source: the authors, 2006.

The French colonial quarter is a result of the French occupation that took place in November 1849. The town is an expanded settlement and its population is a mixture of races due to its nodal position at the crossroad of fundamental ways between the Zab, M'zab and Tell that made of it an important caravan center.

Tourism and Socio-Economic Development of Bou Saada

In this renowned tourist resort there is, among others, the tomb of El Hadj Nasir Ed Din who is in fact the French painter Etienne Dinet. He reached Bou Saada in 1884, became a Muslim and buried in that place after his death. The Arabic name of Bou Saada means the "city of happiness". It is like a museum of the Sahara and Highlands, it contains all the elements, "providing" a synthesis of life almost Saharan. The city lies on a hill, an amphitheater, a circus at its base surrounded by gardens of palms. A typical Ksar, on a beautiful terrace, a green island amidst a sea of sand, which stands out against the Blue Ridge Mountains with sinking roots into the burning sands of Hodna.

The Ksar itself is divided into several parts corresponding to the seven main sections of the Saharan tribes (see figure 3), with traditional earth bricks houses enclosed by high walls and all surmounted by a terrace. The river flows at its feet in a bed deeply incised between banks.

It is fully bordered by date palms, figs, large beautiful plants, between two mountains with a red top. Here dozens of painters also went into raptures.

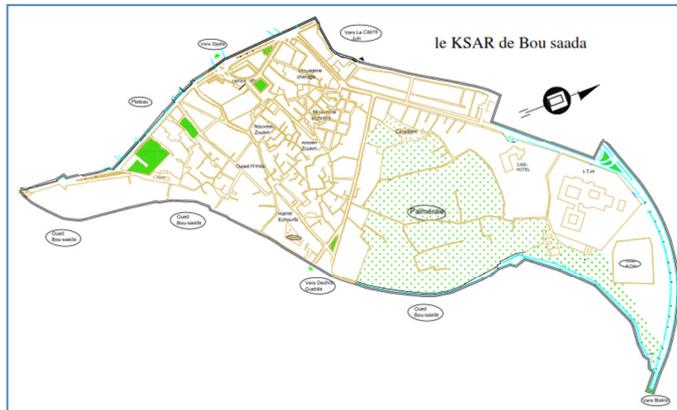


Figure 3: Map of the Ksar
(left: the Ksar and seven tribes, right: the palm groves, bottom: the river Bou Saada).
Source: Master Plan of Bou Saada, 2010.

Bou-Saada may be the only major city in southern Algeria to offer an almost complete touring organization. There are a range of hotels for all budgets, from modest but clean establishment of true luxury hotel like the Caid or Transatlantique Hotels.

The "Moulin Ferrero" is a quite dilapidated mill manufactured in a parade of the canyons happiest effect, fresh water flows along a beautiful garden. Remaining perfect for misanthropic, Moulin Ferrero seems an ideal getaway in the fields of violets and trees of all species along the river. Bou-Saada is still offering excursions on camels, gazelles, the southern cuisine, the expert guides, camel races, bassours contests. The French school, designed by the architect Xavier Salvador, with the "trunks of palm" style is a happy discovery for both modern and local architecture.

The reputation and reality of Bou Saada do not always coincide. But if the tourist destination of Bou Saada is not in question today, and reputation of the beautiful Caid hotel built by Fernand Pouillon is evidence, the economic reality is however needed and herein revealed the typical problems of most Ksours in the Sahara. The image of a small town is reflected by the market regarding the limited farming and handicrafts products encouraged by the diverse tourist potential of the oasis. Seemingly, nothing will happen at the expense of the actual values of the past that embodies the traditional monuments.

From the above data analysis emerges a clearly affirmed urban structure. The network of routes, facilities and trade converge towards the south west of the Ksar and confers it with a small role in the city center. The topography of the site represents a flat ridge that guides most of the pathways.

Conceptual Framework

A strategic planning approach is fulfilled to analyze the Ksar. The methodology used is based on the "SWOT" (strengths, weaknesses, opportunities and threats) analysis as a strategic



planning method to assess the key criteria for a comprehensive safeguarding of the Ksar. The expected results will help to identify possible and appropriate revitalization strategies for economic recovery that will guide investments in preserving this historical city, as an essential part of the national cultural heritage.

Regarding the cultural heritage and identity issues, action for the cultural heritage and economic development depends on:

- The span of action that can be undertaken by the institutions to promote pilot projects,
- How can the local community be involved in the valorization of its cultural heritage?
- How to link political action with professional training in the field of management?
- The incidence of culture as motivation for tourists to visit the city,
- The impact of tourism on city's economy.

Cultural tourism and socio-economic development must be high on the agenda. Cultural heritage contributes to the identity and branding of territory. This identity constitutes the base for sustainable and endogenous development. Heritage includes buildings, monuments, landscapes, urban areas, countryside, buried remains and objects. (1)

Pre-requisites constituting the base for sustainable development:

- The primary responsibility of the public sector to act as the custodian of cultural heritage assets in the respect of cultural specificities of the community,
- The appropriation of cultural heritage by local populations.

Revitalization of cultural heritage, as part of an economic and social system, can be provided by the local market, the local museum, the micro firms producing locally culture-based goods, the tourist industry. The local institutions are involved too in the creation of a cultural district.

Contributing instruments to the promotion and conservation of heritage in Bou Saada:

- Education and access to knowledge as key factors of the promotion of cultural heritage,
- Sustainable cultural and site seeing tourism,
- Urban rehabilitation of the ksar and adaptive reuse of buildings.

The necessity of training courses on policy making and on the economics of heritage:

- To build the awareness of civil society in cultural heritage matters,
- To develop the local building capacity and aim at training trainers, setting training methodologies and producing educational materials.

Other helpful tools deserve awareness; such as cultural events on the site and in relation with the local cultural heritage elements, animation activities, educational campaign and promotion of thematic days to awaken students and scholars.

Ecotourism is a challenge now for the development of Bou Saada. The link between culture and tourism is the most visible aspect of the contribution of culture to local development.

When tourism is identified as part of an overall development strategy, it imposes the identification, protection and enhancement of historic resources.



When heritage tourism is done right, the local residents experience a renewed appreciation for and pride in their local city and its history. The influence of well-planned and well-managed local tourism programs extends to improving the local economy and enhancing the quality of life for local residence. (2)

Tourism promotes new productive and commercial activities in the field of cultural heritage: hotels, restaurants, publications, arts and craft, high quality museum souvenirs, guide services. However, the environmental challenges of tourism and the side effects of its activities should be part of the urban development strategy of the city.

In Bou Saada, sustainable tourism will play a vital role in the success of tourism development if all stakeholders are involved in economic development towards a common goal of both enhancing the economic impacts of tourism, while ensuring environmental protection and preserving different heritage assets of the town. Priority issues are circulation and linkages, image and identity, economic conditions, architecture and streetscape, future development and infrastructure.

Analysis for a Comprehensive Safeguarding of the Ksar

City revitalization is not only limited to monuments, but to a larger scope of old buildings, also dwellings, that can be renovated and re-used for other purposes previously unforeseen. This in turn has many indirect socio-economic impacts and improves the area's image and reputation, which acts as a magnet to businesses.

Nevertheless, there are common problems to face:

- Commercial interests predominate when dealing with poverty and the absence of legal protection of buildings is a threat for cultural heritage,
- Often the property is not interested in rehabilitation and the owners are not open to action.

An action program should be set to:

- Create innovative institutional and financing programs and incentives to be used to facilitate implementation as well as providing direct incentives for the residents,
- Introduce indirect incentives in the form of employment opportunities, neighborhood facilities and training in traditional construction and rehabilitation work.

Preservation can be the tool to create a future in which a stable residential core is enlivened and sustained by a widespread system of small workshops and retail activities, supported by essential infrastructure and community facilities and made more attractive by well-maintained open spaces and monuments. (3)

Improved living conditions will promote a stable population and the kinds of productive activities that come with a steady demand for goods and services and aim at facilitating the gradual rehabilitation of existing residential units and promoting the redevelopment of ruined buildings.

Results



Investing in culture can catalyze economic development. Capitalizing on the resourcefulness of local people to repair buildings, clean and replace old facades, and install new facilities. The project of rehabilitation must be based on two main lines: the safeguard of cultural heritage and social real estate. Upgrading the built environment in Bou Saada is a good challenge to be overcome by:

- Rehabilitation of historic buildings: their long-term preservation is crucial to maintaining the area's architectural character and attracting visitors to the area,
- Reorganization and maintenance of public spaces: upgrading street paving, public lighting and signage, as well as facades and storefronts can do much to attract and enhance commerce,
- Housing improvement: a dual strategy can be pursued, the gradual rehabilitation of existing residential units and redevelopment of ruined buildings and vacant plots into new housing.

The aim of rehabilitation work is to offer a decent work space for the many artisans now accommodated in decaying buildings, improving their working conditions and their output. Real possibilities of undertaking micro-projects to improve the day-to-day life of the population will emerge and local architectural heritage will be recovered.

A Cultural Centre may also provide all the necessary information and organizes guided tours and events to discover the history of the Ksar and its evolution through the centuries.

Conclusions and Recommendations

Institutional co-ordination and community involvement within a gradual process of economic improvement and physical rehabilitation must be viewed in the light of conservation and revitalization needs. Community involvement can achieve lasting results in Bou Saada.

A few important issues:

- Public goods include cultural heritage; therefore the role of the public sector at central and local level as custodian of cultural heritage assets is extremely important,
- Civil society organizations need to be involved at different scales in the consultation and planning of investments.

Local communities should share the benefits so that social development returns may be obtained:

- Secure the wider dissemination of project activities to the civil society through the allocation of specific funding, and promote the preparation of educational material for school children and the civil society,
- Encourage closer contacts between training programs and public/private employers in cultural heritage,
- Ensure that proposed projects include not only plans for immediate results, but also include studies on foreseeable impacts,
- Encourage the emergence of networks of specialized local enterprises in the conservation of cultural heritage,
- Preserve and disseminate local and traditional know-how.

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Regeneration for Urban and Economic Sustainability: Assessment of the U.S. Neighborhood Stabilization Program (NSP-2)

Speaker

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Abstract: *In 2010, Chicanos Por La Causa, Inc. [CPLC], a multistate community development corporation leading a national consortium of 15 nonprofit affordable housing developers, received \$137 million from the United States Department of Housing and Urban Development under Neighborhood Stabilization Program [NSP-2]. As one of the largest federal grants that targets predominately Latino communities in the USA, NSP-2 funding allows consortia of nonprofit housing agencies to acquire, revitalize, and sell or rent foreclosed, vacant and abandoned properties. With funding from the consortium, the paper assesses NSP-2 impact on households, real estate, and housing related measures in the metro areas of Denver, Colorado and Phoenix, Arizona. The study attested to the positive impact of NSP-2 on urban and economic regeneration in metro areas neighborhoods including: augmenting the real estate values, serving Latino population, creating mixed-income communities; and stimulating local economic opportunities through job creation.*

Keywords: *Urban Regeneration, Neighborhood Stabilization, U.S. Housing Programs, Spatial Analysis, Sustainable Neighborhoods.*

Introduction: Sustainability and Regeneration

In the sustainability practices of the U.K., the government has incorporated social, economic, and environmental well-being to the scope of its sustainable development endeavors in the areas in need of urban regeneration; a policy that has been referred to as *Triple Bottom Line* approach (1). Urban regeneration conjures up different stimulus that revitalize economic, social and physical activities in areas where the market decline has not been resolved without government support (2). The scope of urban regeneration varies from large-scale activities promoting economic growth to neighborhood interventions focusing on quality of life improvement. The latter is generally comprised of three distinct phases: 1) remediation including infrastructure provision; 2) development, construction of property asset; and assigning properties to buyers or tenants 3) investment including selling of occupied property assets according to the market rate (3; 4; 5). The definition of urban regeneration is also linked to the recent discussion in the U.S. and Europe amid the recent housing crisis regarding how the private sector finance can be attracted into investing in cities and neighborhoods in



need of urban regeneration, particularly the areas hit by a decline in home ownership rates (3). This discussion, along with the U.S. and European governments' sustainability efforts, led to a search for funding and development diversification, and creating what Pivo and McNamara (6) called the Socially Responsible Property Investment [SRPI], a concept targets maximizing the revenue as well as improvement, and minimizing the risk of transaction of property ownership, management, and development on the community and the natural environment.

Neighborhood Stabilization Program [NSP-2]

Scope and Administration of the Program

SRPI and likewise initiatives led to establishing the Neighborhood Stabilization Program [NSP], which was materialized for stabilizing communities that have suffered from foreclosures and abandonment. The funding for NSP provided by the United States Department of Housing and Urban Development [HUD] was authorized under the American Recovery and Reinvestment Act of 2009 (7). It is also a component of the Community Development Block Grant [CDBG], and the HOME program –offered through HUD- to assure affordability (7; 8). NSP grants are provided on a competitive basis to states, local governments, nonprofits and a consortium of nonprofit entities. It requires that these entities purchase and rehabilitate foreclosed and abandoned homes and residential properties (7).

In addition to developing their own programs and funding priorities, NSP grantees must follow guidelines for spending the awarded funds. For example, they have to use at least 25 percent of the funding for the purchase and redevelopment of abandoned or foreclosed homes or residential properties that will be used to house individuals or households whose incomes do not exceed 50 percent of the area median income. The funding of NSP grant should be allocated for (9): 1) Establishing financing mechanisms allowing the purchase and redevelopment of foreclosed homes and rental properties; 2) Rehabilitating abandoned or foreclosed homes; 3) Setting up land banks for foreclosed homes; 4) Demolishing blighted structures to rebuild it; and 5) Redeveloping vacant properties.

Following these guidelines, in February 2010, Chicanos Por La Causa, Inc. [CPLC], a multi-state community development corporation leading a national consortium of nonprofit affordable housing developers received NSP round 2 grant of \$137 million from [HUD] (10). To administer this grant, the National Association for Latino Community Asset Builders [NALCAB] organized a consortium of 15 different nonprofit housing organizations providing bilingual and bicultural services to support CPLC in program implementation (11). As one of the largest federal grants, this fund targeted urban regeneration of destabilized neighborhoods through the revitalization of single family homes and rental properties in eight states and the District of Columbia. It focused on predominately Latino communities in the U.S. as they have been disproportionately impacted by the foreclosure crisis.

The author of this paper was funded by NALCAB to assess the impact of round 2 funding of the program [NSP-2] on households, and housing related measures in two locations, identified



by the grantees of HUD funding: The metro areas of Denver, Colorado and Phoenix, Arizona. The author and her research team developed an instrument to identify the changes in property's acquired and selling prices and to compare the discrepancies of selling prices of NSP-2 and non NSP-2 houses in the areas where NSP-2 funding was allocated (see Figures 1 and 2). The geo-technology tools of Geographic Information Systems [GIS] were utilized to map the clustered properties and to carry out spatial analysis of vacant and foreclosed properties. Micro geographic areas, known as Census tracts [CT], within the two metro areas were retrieved from program's online portal of CPLC; selected attributes for properties and households within these CTs were then incorporated. A comparison between household income, race, ethnicity, and properties acquired and selling prices was conducted.

The Program: Goal and Objectives

NALCAB and the consortium defined the goal of NSP-2 as to provide funding to cities, states and consortia of nonprofit housing agencies to acquire, rehabilitate, and resell or rent foreclosed, vacant and abandoned properties to qualified buyers to become occupied and maintained, and to contribute to the community through property taxes and provision of safe and standardized housing (12; 13). The consortium led by CPLC, and administered by NALCAB identified the following objectives for allocating the NSP-2 funding:

- Creating jobs in the real estate and construction sectors.
- Stabilizing the real estate values in the areas where all members of the consortium are located; areas that have been hit by foreclosures including:
 - Increasing homeownership as well as available rental units
 - Demolishing blighted properties, and acquiring residential land at affordable prices
- Creating affordable housing for low and moderate-income working households.
- Generating income after the end of grant period –through establishing land banks- that offer hundreds of additional high-quality affordable housing opportunities through the selling of NSP-2 properties.

Methodology: Neighborhood Sustainability and Measures of Regeneration

Stabilization, Regeneration and Sustainability

Following the *Triple Bottom Line* and SRPI principles, CPLC and NALCAB established a mechanism for NSP-2 to create economic opportunities within the targeted geographic areas, known as Census Tracts, within Denver and Phoenix metro areas. Through these opportunities, the program not only rehabilitated vacant properties, and redeveloped new homes and rental properties; but also contributed to the creation of new local jobs including: construction workers, realtors, inspectors, landscapers, property management and maintenance professionals, roofers and skilled tradesmen. According to the estimates of the President's Council of Economic Advisers, the \$137 million federal investment in the consortium projected to create or retain approximately 1,500 jobs nationwide (13, 10). Like



the CPLC consortium, different organizations across the U.S. have established partnerships with other entities to create a successful model for urban regeneration, through stabilization and sustainability approaches for neighborhoods. In Syracuse, the New York Home Headquarters [HHQ] organization is one of these programs in which HHQ collaborated with residents and other organizations, including Syracuse University as well as Syracuse Center of Excellence, to develop a strategy for sustainable development and retrofit of an existing neighborhood. The project, known as the Syracuse, Art, Life, Technology [SALT] District, allowed HHQ to leverage the complementary resources of its partners in order to enhance sustainability in its own projects, and helped the SALT District become the first existing neighborhood in the country to achieve a stage of LEED-ND certification (14). This has in turn attracted residents and businesses to live and work in an area previously suffered from high vacancies and disinvestment.

Another example is the Near Westside Initiative, a nonprofit organization focusing on economic development, housing revitalization and quality of life enhancements. The initiative was created in 2007 by joint-forces of Syracuse University, the Gifford Foundation, and HHQ. HHQ was brought into the partnership for its expertise in improving the housing stock, economic development, and attracting artists to live and work in the neighborhood. According to Gass, this multiple facets initiative focused on neighborhood stabilization through recovery and growth plans for the protection of future generations and the support for sustainable building practices (14).

Measures of the Neighborhood's Urban Regeneration

To assess the direct and indirect impact of urban regeneration projects that encompass critical measures of neighborhood change, ten measures have been considered vital (15). These measures include: Demographic changes (i.e. ageing, migration and mobility); education and skills; employment; health and safety; housing and environmental health; identity, sense of place and culture; participation, empowerment and access; social capital; social mixing and cohesion; and well being, and quality of life.

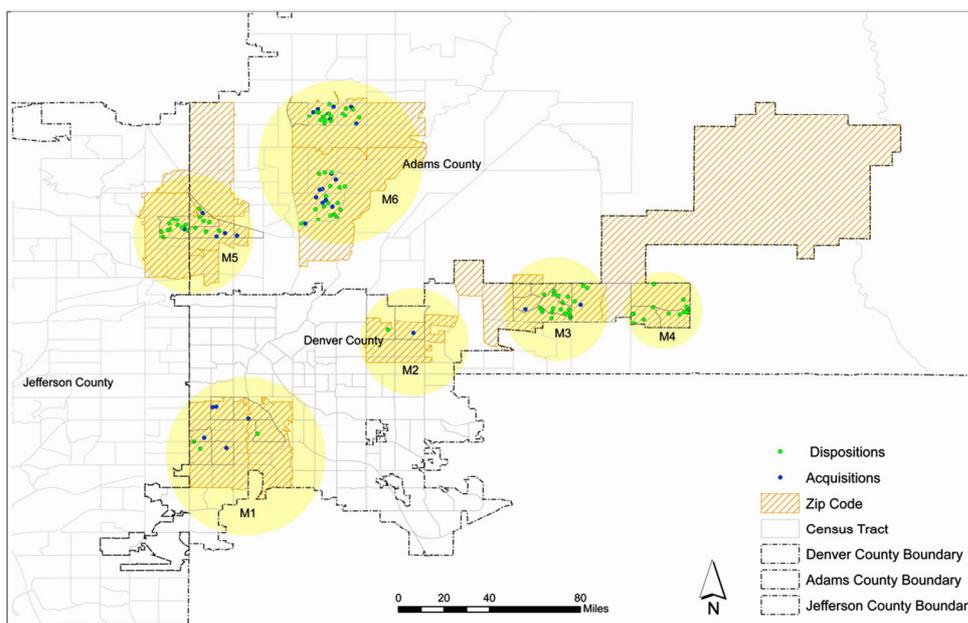
Some of these measures, in addition to other attributes contributing to the real estate measures, were integrated in the parameter we identified for the assessment of NSP-2 impact. The approach employed in this paper, starts with setting up a baseline profile for the population and housing characteristics of the Counties identifying the Denver metro area including (Denver, Adams, Jefferson), and Maricopa, the only County in Phoenix metro area. Utilizing the data portal of the U.S. 2010-Census Bureau (16; 17), the following attributes were incorporated in the assessment: count of housing units and households in all NSP-2 census tracts [CT], the geographic units commonly used for the demographic and economic disparity analysis in the U.S. This was followed by analyzing NSP-2 households' income in each census tract, and comparing it with the median household income [MHI] of existing population in those tracts. A spatial analysis model-using Geographic Information Systems

[GIS] - of foreclosed and vacant properties in NSP-2 census tracts of Colorado and Arizona was then utilized. The model helped in identifying –through geocoding process- the location, previously unavailable, of rehabilitated/or newly constructed properties as well as compare their respective CTs vacancy and foreclosure rates.

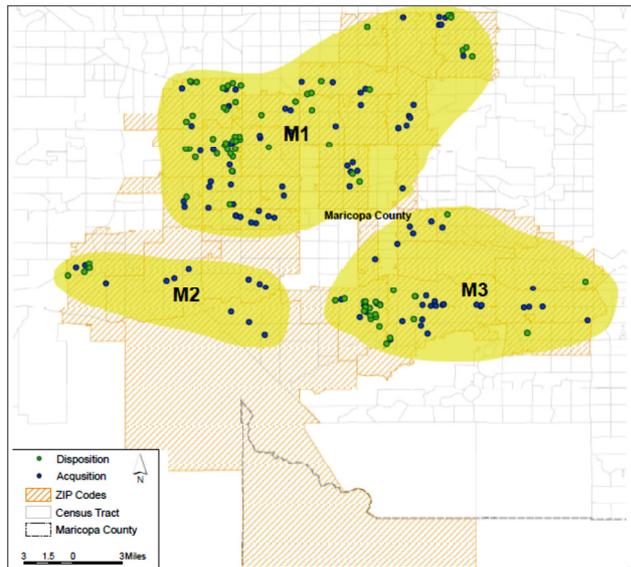
The model also illustrated the purchased and sold properties, as well as the newly constructed properties clustered by their respective locations within their respective CTs (see Figures 1 and 2). Based on the clustering pattern of purchased/sold properties, six CTs within both metro areas (two in Colorado and four in Arizona) were selected to further analyze race and ethnicity of existing households. The selection process was facilitated with the funding agency to focus on the areas where an anticipated rational impact of NSP-2 is likely to occur. Race and ethnicity were compared with those of the NSP-2 program households. Finally, a detailed analysis for the real estate value was conducted using a comparison of the unit’s price per square foot of the NSP-2 properties and other non-NSP 2 properties located in the same residential community within each CT.

Results and Discussion

Within the two metro areas of Denver and Phoenix, 65 census tracts were found to have successful selling of rehabilitated and redeveloped properties through the funding mechanism established in NSP-2. The following section highlights the major findings of the urban regeneration process of the targeted CTs in both areas measured by the indicators developed from the literature and facilitation with the funding agency [NALCAB]:



*Figure 1:
Neighborhood
Stabilization
Properties in the
Metro Area of
Denver, CO*

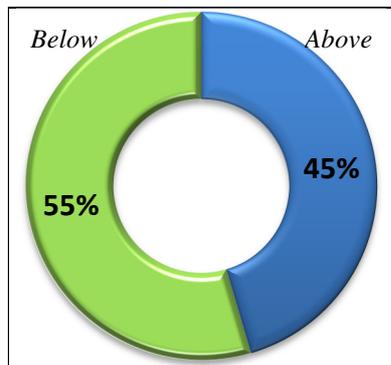


*Figure 2: Neighborhood Stabilization
Properties in the Metro Area of Phoenix, AZ*

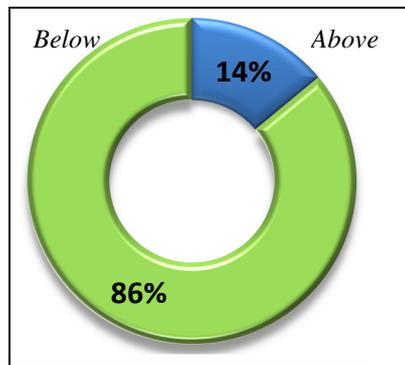
- 1) Of the total 65 census tracts, 22 were located in Colorado where NSP-2 is administered by Colorado Rural Housing Development Corporation [CRHDC] and Del Norte consortium members. The 43 other tracts were located in Arizona where NSP-2 is administered by CPLC. In both states the majority of acquired and sold properties were primarily located in urbanized areas in the Denver metro area, in Colorado; and in the Phoenix metro area, in Arizona. A fewer number of purchased and sold properties were located in five rural counties in southern Colorado and southern Arizona, which were omitted from this study and allow the focus to be on urban regeneration in metro areas.
- 2) The profile of households allocated by NSP-2 to Colorado CTs (see Figure 3-a) indicated that: 45% of NSP-2 tracts, a total of 10 tracts, have median household income [MHI] of the program households above the 2010 median income of the existing households in these CTs. The remaining tracts, 55% of the NSP-2 tracts, a total of 12 tracts, were below the 2010 MHI of existing households in these CTs. This balance between the percentage of census tracts below and above the existing MHI helped improve the neighborhood quality and housing conditions, and supported the mixed-income policies of HUD.
- 3) Figure 3-b shows that of the 43 census tracts in Arizona, the median household income in 14% of the NSP2 tracts, a total of six tracts, have median household income [MHI] of the program households above the 2010 median income of the existing households in these

CTs. The remaining tracts, 86% of the NSP 2 tracts, a total of 37 tracts, were below the 2010 MHI of existing households in these CTs. This proved that NSP-2 in Arizona sold the rehabilitated and the newly constructed properties to a majority of households with income below the existing CTs MHI. This created revenue, but could question the likelihood of these households to maintain a sustainable mortgage and tax payment. Yet, it highly supported the mixed-income policies of HUD.

- 4) NSP-2 contributed to maintaining continuous payment of mortgages and property taxes through increasing the rate of home ownership in the respective CTs where NSP-2 was administered, an income generation for the land bank investment that maintains the sustainability of the program; and revenue helps stabilize the neighborhoods and increases future home ownership.
- 5) This analysis also provided a clear evidence to support the NSP-2 objectives of stabilizing real estate values in communities that have suffered from high foreclosure and vacancy rates. The evidence is driven from the foreclosure data, vacancy data, and percentage of population below poverty data within the CTs where CSP-2 was implemented.



3-a



3-b

Figure 3: NSP-2 households' income Levels (Blue: program's households with income above existing CT households' median income, and Green: program's households with income below existing CT households' median income), in Colorado (Figure 3-a);

- 6) Total price per square foot for rehabilitated or newly constructed properties showed market equity. The majority of these properties were \$5 per square foot more or less than their peers in the same market. This analysis showed an increase in the revenue in Colorado and Arizona which is an asset to maintain the same quality of NSP-2 neighborhoods in order to sustain the real estate market equity.
- 7) This paper attested to the program achievement in fulfilling its main objectives and proved the positive impact on real estate values in the neighborhoods where NSP-2 was implemented. The overall increase in selling price of all properties ranged from 5.7% to 140.2% (with an average increase of 41.43%). The results also showed that NSP-2 not only augmented the real estate values and promoted urban regeneration in previously-destabilized neighborhoods in Denver and Phoenix metro areas, it also supported mixed-income policy; served Latino population; and stimulated economic opportunities through the creation of construction related jobs.



Limitations, Recommendations, and Further Studies

This paper addresses the impact of purchased, rehabilitated, and redeveloped properties of NSP-2 in two metro areas in the U.S.A: Denver, Colorado and Phoenix, Arizona. The impact analysis addressed economic issues such as median household income of the new owners/tenants; housing measures (i.e. vacancy and foreclosure counts, change in properties selling price, and price per square foot). The study however omitted several attributes such as population density, housing density, education attainment, employment, or changes in property tax in the CTs where NSP-2 was administered; all of which could be important variables that could contribute to the research findings, and its recommendations. Despite these limitations, the urban regeneration process in the two metro areas had a significant impact on the real estate market in on the census tracts level. NSP-2 properties clustered in six CTs (two tracts in the Denver Metro area; and four tracts in the Phoenix metro area) had a substantial increase in properties' selling prices, and consequently in construction-related jobs. The regeneration process could also be implemented in other cities and town where a high count of vacant properties due to the foreclosure took place; and an increase of the percentage of households with median income slightly above the existing MHI in the future program areas is recommended. It is also recommended that further impact assessment studies of NSP-2 implementations needs to be conducted in other major metropolitan areas such as Baltimore, Maryland; Washington D.C.; Chicago, Illinois, and El Paso, Texas. The results from these suggested studies would establish a rapport defining the impact of the urban regeneration process on market, job creation, and neighborhood quality.

Acknowledgement

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Session 90:

What capacity does the construction sector have to absorb its own waste and by-products?

Chairperson:

Díaz Camacho, Miguel Ángel

President of ASA (Association of Sustainable Architecture), Spain



Waste – a Resource for Sustainable and Resilient Future Cities

Speakers:

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Abstract: *Our future building material for sustainable and resilient cities might already exist in our current urban systems: Waste. By 2025, the growing world population and prosperity will have doubled the annual production of Municipal Solid Waste. This paper proposes to activate this resource for the urban construction process within thinking of circular metabolism whereby the city is constantly producing the very matter it needs to grow - without exploiting natural resources.*

Cities, which sustain themselves by using already existing, discarded resources, not only efficiently answer the pressing issue of waste management, but also benefit from a larger economical impact. This matter's use, re-use, and potential for re-placement of other materials are the main steps in creating identity, resource efficiency, and local value chains while decreasing the dependency on imports. Refuse products have the potential to be a key factor of future resilient city concepts.

Keywords: *waste, construction, straw, plastic, design, building, material*

Waste as Resource

Waste is the result of any human action and interaction, bringing raw natural materials – understood so far as our sole form of resources – from one stage of being into another, by applying intellectual skills and various forms of energy. In this sense, waste was seen for centuries as an entity, which neither belonged to the family of natural resources nor to the one of finished products. Waste is so to say a by-product, unable to be categorized in our dialectic understanding of ‘raw’ or ‘configured’. This paper tries to unfold the possibility to understand waste as an integral part of our definition of ‘resource’ and therefore as a necessary substance or mere matter from which to construct or configure a new product. But at the same time, the product itself could be seen – after its first lifespan – as the supply source for other artefacts. This metabolistic thinking understands our built environment as an interim stage of material storage.

Waste Management and Recycling

During the 1980ies and 90ies, recycling programs started to emerge in the industrialized world. Waste was not seen anymore as merely unwanted or useless substance, but as a resource for new products. The remains of incineration plants have for example been recycled



by many nations as landfill materials in order to reclaim land from the sea. Private companies entered the markets of mostly developed countries, attracted by the incredible potential of collecting solid waste materials to recycle them for a circular industrial production process. Today, most industrialized nations introduced organized recycling concepts in their communities, even so the re-use rates seem to be stagnant since the end-1990ies.

In recent years, the challenge for society became more and more how to minimize our waste production of inorganic substances and to convert the remaining – maybe unavoidable waste – into a resource. This is the key point when talking about a minimum or even zero-waste society, following the four “R”s: Reduce, Reuse, Recycle, and Recover. This hierarchy of waste management, as it is often called, aims for a total circular metabolism in order to avoid any disposal. A definition of such a zero-waste-philosophy was developed by the *Zero Waste International Alliance* in 2004: “Zero Waste is a goal that is ethical, economical, efficient and visionary, to guide people in changing their lifestyles and practices to emulate sustainable natural cycles, where all discarded materials are designed to become resources for others to use.”ⁱ

A similar model, called “Cradle to Cradle”, created by architect William McDonough and chemist Dr. Michael Braungartⁱⁱ, took a similar direction. In their book “Remaking the Way We Make Things”, the authors suggest a logic of production, which is based on a completely closed resource cycle. Every product – once created out of natural resources including water and energy – should be designed or composed in such a way, that it can enter the production cycle again in an endless loop without polluting or disturbing our ecological system. This is in contrast to a Cradle to Grave ideology, which is the dominant system in our societies so far.

Cities as Resource

Urban Mining is a rather young occurrence, embracing the process of reclaiming compounds and elements from wasted or undesired products or buildings, which contain high levels of valuable materials. In their text “Mine the City“, Ilka and Andreas Ruby describe the contemporary phenomena of a shifting awareness, that raw materials are not to be found anymore in a “natural” realm, but more and more in the “cultural” domain of buildings. “The material resources of construction are becoming increasingly exhausted at the place of their natural origins, while inversely accumulating within buildings. For example, today there is more copper to be found in buildings than in earth. As mines become increasingly empty, our buildings become mines in themselves.”ⁱⁱⁱ In their view, the city is to be seen as a container of buildings and mines as the same time, much needed for its own reproduction.

In Germany alone, 8,4 billion Euros were saved in the year 2009 by recycling valuable matters from waste products, and it is believed that by 2015, this amount can easily double according to the *Institut der deutschen Wirtschaft IW Köln*.^{iv} Urban Mining demonstrates a potential and possibility how waste products can be resourced at the end of their first life span, entering a second or third by being transformed, reshaped, remodelled or reconfigured. But it also opens up the questions, if the waste state of a product should not be the starting



point of its design.

According to the Worldwatch Institute, world's growing population and prosperity will double the annual production of Municipal Solid Waste of today by 2025. This means that its volume will most probably increase from today's 1.3 billion tones to 2.6 billion tones per year.^v Are we able to activate this material for the urban construction process? If so, a thinking of a circular metabolism could emerge whereby the city is constantly producing the very matter it needs to grow without exploiting natural resources. Concepts for future cities call for architects and designers to think, work, and create in a holistic, circular manner. This framework, incorporating ecologic, industrial, social and economic principles, aims to create efficient systems where materials live through several states of formation and use over their life span and are never reach the stage of discarded matter.

Densified Waste Materials for Construction

The most obvious and direct way to process waste materials into building construction elements is densification. The garbage press, today a standard equipment in solid waste management and already introduced in England in the 19th century, is mainly intended to reduce the volume of refuse through compacting. One option is to place the material in a mould and compress it into manageable bales, which are then striped in order to keep them from dissolving. Alternatively, the loose stuff is pressed into small pellets uniform in shape and with a much higher bulk density compared to the incoming material. Many plastics, sorted or unsorted, lend themselves to densification and are subsequently fed into an extrusion process to create the new products. Pellets produced out of waste resources such as saw dust, wood chips, bark remains, recycled paper, textile residues, or even manure, lately became an important energy source for heating systems worldwide. In both ways of processing, the original material remains unchanged in terms of chemical composition; it is also neither disintegrated or manipulated in its physical form, or mixed to form composites. The act of pressing stores energy in the system, resulting in a higher state of material properties. The ensuing reduction of volume is not the main goal, rather a tool to activate a specific potential within a specific waste product. Following this concept, the Chair of Architecture and Construction at the Future Cities Laboratory developed two prototypes in recent year activating the potential of PET bottles and straw through desification: Airless and SECU.

Case Study: Airless

Polyethylene Terephthalate (PET) is one of the most common consumer plastics world-wide, best known in production of food and beverage containers. Although intended to be recycled in a circular economy mentality, in reality, the majority of PET products world-wide end up as waste - despite the fact that such items are typically easy to be recycled, forming granulates or flakes that can be turned into new products. By contrast, when PET is discarded, many problems arise: this material is extremely long-lasting and hardly degradable. Once it enters the food cycles, for example floating as fine aggregates in the oceans, it remains for a long time in our environment and may harm organisms like fish and ultimately human beings. Incineration is no real alternative, as it produces toxic by-products that are harmful for our environment and health.



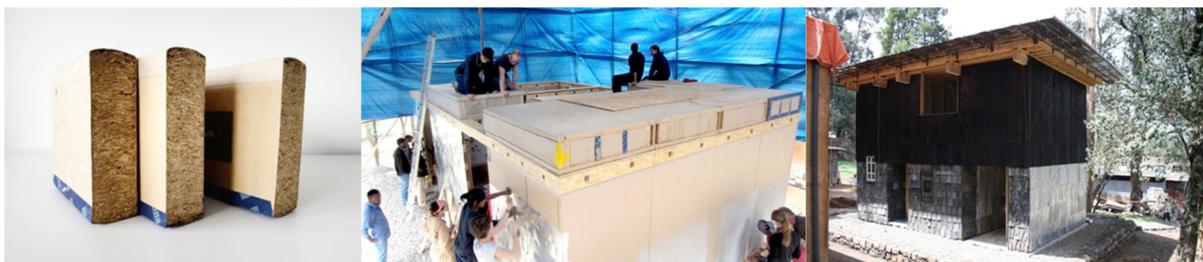
Airless: (1) Raw Material, (2) Construction and (3) Pavilion Prototype

New technologies may allow to pursue the strategy of extending the PET waste products recycle process and store the material for a certain time in our built environment. Following this approach, Airless prototype built by the Chair of Architecture and Construction Dirk E. Hebel at the ETH Zurich, uses empty PET bottles by packing them into prefabricated arch-shaped and airtight foil tubes that are vacuumed once they are completely filled. This process creates a lightweight and extremely efficient load-bearing element that can be used to create large-span spatial structures. The ensuing system can be controlled according to various parameters: the higher the negative pressure resulting from the vacuum condition, the higher is the friction between the bottles, resulting in a more rigid system. The maximum load capacity of such elements depends also on the quality of the bottles used. Closed bottles, containing still some amount of air, have a higher resistance against vacuumization and also against pressure, they are harder, while open bottles form a softer system with less capacity to absorb external forces.

Case Study: Sustainable Emerging City Unit (SECU)

Straw, an agricultural by-product still considered waste in many societies, due to the ubiquitous habit of burning it on the fields after harvest, creating harmful substances that are emitted into the air. Straw and other organic materials are biodegradable and can be composted to enrich the soil, hence should remain part of an organic life cycle. We see a potential in abstracting these from the regular cycle for a limited period, using them as a building material before feeding them back into the earth's natural metabolic system.

The Sustainable Emerging City Unit (SECU), a prototypical construction by the Chair of Architecture and Construction at ETH Zurich together with its partners at EiABC, Ethiopia and the Bauhaus University, Germany, capitalizes on this rich resource and opens up the possibility of building double-story housing structures, using this widely available building material for large-scale housing projects in emerging urban settlements in Ethiopia. The project responds to the difficult availability of construction materials in rural areas of developing territories and incorporates waste products in the design and construction process.





Sustainable Emerging City Unit (SECU): (4) straw panels, (5) Construction and (6) Proto-Typology

Following this design strategy, a complete housing structure was made out of structurally active compressed straw board panels, supplied by the company Strawtec. Through heat exposure, the starch in wheat straw is activated and acts as a natural glue, without requiring other chemical additions, to produce panels that are easy to handle on construction sites. The flat boards used in this project are 60 mm thick and cladded on each side with recycled cardboard. The strawboard walls are self-supporting and do not require any kind of studwork. The material's excellent physical properties include high soundproofing and fire-protection ratings, due to a double-layer system with a thickness of 120 mm. The panels can be drilled, screwed, and even glued together to form larger units and systems. In addition, the material is 100 % recyclable and biodegradable, with an excellent CO₂ footprint and a manufacturing process that uses only 10 % of the energy needed to manufacture a comparable standard drywall system.

Special attention was given to the waterproofing of the material by using large roof overhangs and cladding materials that can be recycled and transformed, for example from the inner tubes of old car tires.

Designed Waste Materials for Construction

An alternative to re-using waste is the ongoing, still futuristic idea of specially designed goods that potentially never turn into waste: they spend their material lifetime in a constant state of reuse, readaption, and recycling without having to be densified, reconfigured, or transformed. Throughout their life cycle they are meant to keep their original form, properties, and material composition while their functions may change dramatically. Once such products have been used in the way and at the location for which they were originally destined, their particular character allows for yet another – second, third, even fourth – life cycle with different functions. They might also be combined (without being mixed) with other materials into a heterogeneous condition of being, maintaining their ability to change their state again when required.

This approach questions the common recycling strategy as implemented so far in our society – which is, in fact, a down-cycling concept, meaning that the quality of a material is diminishing when combined with other similar products. A good example for this phenomenon is the steel industry. Despite the fact that steel can easily be melted again, reshaped, and reformed, this process usually goes along with a loss of value and quality. Each repetition of this cycle more and more reduces the original material quality.

The question of design therefore becomes a core issue when discussing alternative concepts of building from waste, where a design would allow for a second use without change. This could be called a smart design approach, which takes the question of sustainability seriously in the sense of looking far ahead instead of satisfying only the immediate need or demand. The Chair of Architecture and Construction Dirk E. Hebel with partners designed one such

exemplary building material called United_Bottle.

Case Study: United_Bottle

50 billion one-litre plastic bottles are currently sold in Europe alone every year^{vi}. Since a compulsory bottle deposit was introduced in most European countries in the last two decades, the recycling rates on the continent increased dramatically, while numbers worldwide are still disappointing. Overall, the majority of bottles seen on a global scale are not returned to the recycling process – especially in developing territories – and usually end up as waste material since recycling mechanisms are not in place.

United_Bottle suggests to introduce a new design strategy which allows a regular plastic bottle also to be used as a building element and thereby avoid having to discard containers made of Polyethylene Terephthalate (PET) or Polypropylene (PP). The design prepares the bottle for its secondary use without diminishing the functionality of the first. It is equipped with two inward and two outward-oriented tucks, fitting into each other perfectly. With this added element, each bottle can be connected to four other bottles surrounding it, by sliding one tuck into a corresponding tuck of its neighbour. In principle, this system allows endless wall constructions, without using any mortar or gluing device. Once connected, the bottles form a horizontally as well as vertically linked structural system, similar to a regular masonry wall.



United_Bottle: (7) bottle design, (8) constructed wall and (9) prototype shelter for Van Allen Institute Exhibit

Additionally, the bottles can be equipped with locally available substances in order to increase their physical properties. Sand, earth, or any kind of liquids can be filled in to stabilize specific areas of a United_Bottle structure. This process adds weight to the bottles, which even allows for the assembly of foundation elements. Also materials such as hair, wool, plastic films and bags, paper, textiles, or feathers can be stuffed into the empty containers. This will increase their thermal, acoustic, or aesthetic properties. Ideally, the United_Bottle would become a standard in local sales and thus be instantly available whenever the need for an easily applicable building system arises.

A Resilient City

Different techniques and ideas were developed over the last decades of how to transform waste into a desirable and therefore valuable good, out of which two have been presented here today: Densified and Designed Waste Materials. Nevertheless, most of today's construction



materials are based on knowledge, ideas, technologies and cultural understandings, which were developed in the age of industrialization with an uncritical view towards the question of sustainability, environmental protection and resource availability. All this at a time, where waste was not seen as a resource at all, but mostly as a problematic matter, as we described above.

The fast-changing world, its urbanisation and constant growth however call for new paradigms. A resilient future city should first of all look at its own production when searching for resources to sustain this desired growth. And one of the most easily available, 'renewable' resources in cities of our time is unquestionably waste. The above discussed prototypes are possible examples on how the future city can start to utilize this so far unrecognized resource.

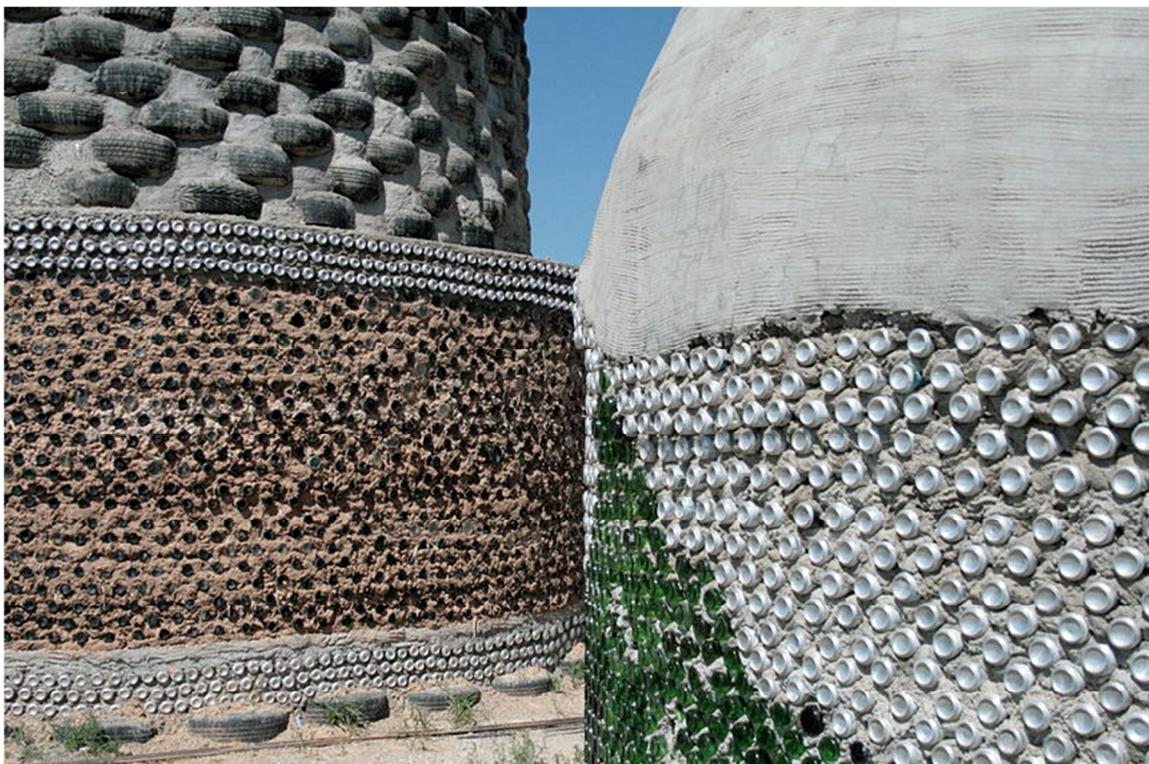
EARTHSHIPS: The buildings of the future.

Speakers:

Soriano, Marta, Camacho2, Jesús.

ECOART-DIDACTIC, Barcelona, Spain

Abstract: Earthships are houses built based on natural and residual materials, such as used tires, empty glass bottles and aluminum cans. (Imagenumber01.jpg)



(Imagenumber01.jpg)

The term “Earthship” is a registered trademark of Michael Reynolds, an american architect who built the first earthship in the early 1970s.

Earthships are comfortable, long lasting and totally self-sufficient buildings, that’s the reason why they are called ships. This technique of construction aims to reduce costs of building materials, confer housing the status of autonomous regarding to networks of electricity, water, trash, etc., and allow its low-pollution integration into the environment towards conventional homes uses materials that require a lot of fossil fuels.

The concept of this type of building is to use readily available sustainable materials and resources available from its natural surroundings to recycle their own garbage and wastewater and to use renewable energy, like the sun, water and wind.



Earthships produce water and electricity for its own use. They need to be able to create their own utilities, and to handle the three systems of water, electricity and climate, in order to be entirely self-sufficient. They rely on natural energy sources and are independent, free from the electrical and water lines. They are designed as structures that are free of the constraints of centralized utilities, on which most modern shelters rely.

Electricity is generated by solar panels and stored in batteries. The roofing collects rainwater that is filtered and used for drinking and various household activities such as cooking and washing. Used water from sinks and showers – graywater- is reused to water indoor plants and after that for toilet flushing.

Keywords: Earthships, Sustainable buildings, Sustainable designs and construction, renewable energy, Permaculture, self-sufficient buildings, recycling, sustainable architecture, radically sustainable living, greywater.

Biotecture: Architecture and Wisdom

The fifth of the Human Rights is the right live in a decent and adequate house. There are more than 2 billion homeless people in the world.

So far it has not been possible to solve the immense needs of habitat in many countries. Building Earthships is a solution for many problems: environment, habitat, garbage, etc.

We need more wisdom, more awareness of where we are and what environmental impact we are causing to our ecosystems, more common sense in order to live in harmony with nature.

Earthships can adapt to different climates and are being build worldwide. In North- and South America, the Carribeans, Asia, Africa and Europe. The colder climates require the use of stronger insulation on the outside of the tire walls. Air conditioning and maintenance costs are low since 3 of its walls are covered with Earth, which offers protection for temperature changes.

Scrap tires are converted into usable "bricks" (Imagnumber01.jpg). The tire walls are additionally strengthened by using concrete in the tires on the ends. Earthships are not limited to tires – any dense material with a potential for thermal mass, such as concrete, adobe, earthbags, or stone could theoretically be used to create an Earthship. Internal walls are often made of recycled cans joined by concrete and usually thickly plastered with adobe.



imagenumber02.jpg

Additional benefits: Earthships are resistant to earthquakes, tornadoes, floods or other natural disasters. A fully rammed tire is massive enough to surpass conventional requirements for structural load distribution to the earth.

The roof is made using wooden support beams which rest on the tin can walls. The roof as well as the north, east and west facing walls of an Earthship are also heavily insulated to prevent heat loss.

The rammed earth tire are its high load-bearing capacity and its resistance to fire. The tires full of soil do not burn when exposed to fire.

External coatings:

We can make beautiful and original coatings for external walls with various small light objects. Some of the waste that you can use to coat the walls are: used pens and markers, sticks of ice cream, small boxes, broken watches, old cutlery, damaged tools, bolts, small metal objects, coil springs, hooks, pins, hair pins, old jewellery, broken glasses, pieces of puzzles, expired credit cards, empty perfume bottles, caps of cosmetic products, small aluminum cans marbles, old CD and DVD, small toys, etc (imagenumber 02.jpg, imagenumber03.jpg, imagenumber4.jpg)



imagenumber03.jpg



imagenumber04.JPG

Drinking water, gray water and black water:

Earthships are designed to catch and use water from the local environment without bringing in water from a centralized source. Water used in an Earthship is harvested from rain, snow, and condensation. As water collects on the roof, it is channeled through a silt-catching device into a cistern.

The cisterns are positioned so they gravity-feed water organization module that filters out bacteria and contaminants and makes it suitable for drinking.

Water collected in this way is used for every household activity except flushing toilets. The water used for flushing toilets has been used at least once already: frequently it is filtered waste-water from sinks and showers, and described as "greywater".

Greywater made at earthships is not polluted enough to justify treatment. Its "pollution" being usually just soap, is often not environmentally damaging. It is used within the Earthship for a multitude of purposes. It is unsuitable for drinking,

The first Earthships used composting toilets which use no water at all. With the new greywater treatment, the general water system has been redesigned and Earthships now can have flush toilets.

Blackwater from flush toilets is not reused within the Earthship. It is sent to a solar-enhanced septic tank.

Electricity:

Earthships can be considered as an off-the-grid housing, meaning that they can live away from public utilities and fossil fuels such as gas, electricity, water or sewage.



Earthships are designed to collect and store their own energy from a variety of sources. The majority of electrical energy is harvested from the sun and wind. Photovoltaic panels and windturbines located on or near the Earthship generate energy that is then stored in several types of batteries.

If additional energy is required, it can be obtained from gasoline-powered generators or by integrating with the city grid.

Temperature and ventilation:

Earthships are primarily designed to work as autonomous buildings using thermal mass construction and natural cross ventilation assisted by thermal draught to regulate indoor temperature.

The sun provides heating, ventilation, and lighting. To take advantage of the sun, the front and principal wall of an Earthship, which is nonstructural and made mostly of glass sheets, is solar-oriented and angled so that it faces directly towards the equator, perpendicular to light from the winter sun. This positioning allows for optimum solar exposure: maximum exposure in the Winter and lesser exposure in the summer. Windows on sun-facing walls are placed so that sunlight is shone inside the house to be used for lighting and heating. The buildings are often horseshoe-shaped to maximize natural light and solar-gain during winter.

The thick and load-bearing walls of an Earthship made from earth-filled tires, hold up the roof and provide a dense thermal mass that will soak up heat during the day and radiate heat during the night, keeping the interior climate relatively comfortable all day.

Earthships use the properties of this natural phenomena from the thermal mass. Passive solar heating and cooling naturally regulates the interior temperature during both cold and hot outside temperatures. This natural heat insulation and ventilation, stabilize and maintain its inside temperature. They rely on a balance between the solar heat gain and the ability of the tire walls and subsoil to transport and store heat.

The large series of windows and the use of tires characterize the earthsheltered building. Earthships usually use their own natural ventilation system. It consists of cold air coming in from a front window, especially made for this purpose and flowing out through the skylights that are placed on the Earthship. As the hot air rises, the system creates a steady airflow of cooler air coming in, and warmer air blowing out.

Burocraty:

The permit office in the community where you plan to build an Earthship will determine if you can easily obtained full planning permit for buildig or you are invitd imnto a burocratic war. This constructive system does not require foundations. In a a couple of hours you can delete the entire building without any problem.

Economy and self construction:



Earthships are economically feasible for the average person with no specialized construction skills to be able to create. Construction drawings and training should enable people to build their own off-the-grid Earthship home and become independent from public and commercial utilities.

The speed of its construction and its very low cost, compared to traditional construction, makes easy a house extension.

This type of construction is an architectural model that fits into the parameters of the Permaculture movement holistic whose goal is to repair the damage caused to the ecosystems, managing resources in a sustainable manner to the mutual benefit of humankind and nature. It integrates harmonically the House and the Landscape. Permaculture also includes aspects of natural treatment of water, renewable energy, community development and bio-construction, among others.



Recycling Construction Waste as Action to Minimize the Environmental Impact

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Abstract: *In Mexico, Construction and Demolition Waste (CDW) generated an environmental, social and economic challenge. Only in the Federal District, with a population of 8'720'000 inhabitants during 2005, the total volume of CDW that was generated, represented the equivalent 844 kg per capita annually, and as a result, the increased number of illegal landfills, given the emerging legislation and the lack of control over these residues. The objective of the work is the recovery through recycling of CDW in the production of manufacture of construction materials in order to minimize the environmental impact in Pachuca city. Positive results in comparison met with Mexican construction standards and determined the feasibility of use to make concrete pressed blocks and low resistance concrete was determined, same that are widely used in the study area.*

Keywords: *Construction and demolition waste CDW, Recycling, Environmental Impact.*

Introduction

Within industrial activities, the construction activity is the largest consumer of raw materials, together with associated natural resource industries, such as wood, minerals, water and energy. An optimal strategy for minimizing the environmental impact consists in using solutions that decrease in a balanced manner the materials effects on the environment, i.e. on energy consumption to produce them and install them, waste generated when they are manufactured and during on-site installation, as well as direct and indirect than this pollution produced. Construction and Demolition Waste (CDW) is that generated during construction, renovation (expansion or recovery) and demolition of residential an non-residential buildings (industrial, commercial, institutional, civil infrastructure, etc.) The term revalorization is used for those actions that stimulate the recovery and reincorporation of CDW to a life cycle or productive cycle, either in the construction industry or as raw materials for other activities^[3].

The practice of recycling of CDW is a process already strengthened in several countries. In some regions of Europe, recycling is a cultural issue, which stems from the difficulty of obtaining natural raw material (sand and stone) and the availability of premises for storage^[1].

In America, countries like Canada, United States and Brazil, carry a record CDW production and control over plants for recycling, otherwise, the Spanish-speaking countries, where the lack of legislation and control over these scraps, make it difficult for their detailed study^[7]. In Mexico, there are not specific studies on the characterization and generation of



CDW at the national level, the management of CDW not managed sustainably, by contrast, cause high environmental costs by the uncontrolled dumping of the same.

The present job takes on the strategy of revalorization of CDW in order to minimize its environmental impact. The aim of this investigation is to make a contribution to the proposals for the adequate management of CDW in the State of Hidalgo, central Mexico by elaborating a construction material out CDW from the area of Pachuca, the capital of Hidalgo.

Area of Study

The State of Hidalgo is located in the Central Highlands of the Mexican territory, on a surface of 20,905.12 km², belongs to the South-central subregion, between latitudes 19° 35' and 21° 25' North latitude and 97° 58' and 99° 52' West longitude; with a population of 2'732'894 inhabitants. It is comprised of 84 municipalities, organized in 11 economic regions: Pachuca, Tulancingo, Tula, Huichapan, Zimapan, Ixmiquilpan, Actopan, Metztlán, Molango, Huejutla and Apan.

The Pachuca city is the capital of the State of Hidalgo; it is located in the central part of the country and between the coordinates 20° 07' North latitude, 98° 44' West longitud, with a height of 2'400 to 2'800 meters above sea level. Located in the Central-East of Mexico; found 96 km north of Mexico City. The Pachuca metropolitan area has a population of 511'981 inhabitants in an area of 1358.8 km², and consists of 7 municipalities of Hidalgo (Pachuca de Soto, Mineral del Monte, Mineral de la Reforma, San Agustín Tlaxiaca, Epazoyucan, Zapotlán and Zempoala), being the thirty Metropolitan Zone of Mexico.

Environmental Impact of the CDW in the area of study

In order to identify the impact of CDW in the study area, a method based on the cause-effect method derived from the Leopold matrix ^[4] to combine de qualitative assessments and, the quantitative assessments in the impacts identification, based on the Domingo Gómez Orea ^[6] method were used. The sums of the values of importance, calculated in rows, allow to obtain an idea of the environmental sub-factors affected; for this case of study, the soil quality due uncontrolled dumping. In a similar way, the sums of columns allow to identify the actions that produce greater impact. In the case of CDW, the actions are the dumping control and the collection, classification and recycling of CDW.

This action correspond with the following effects:

- Changes in the use of soil;
- Pollutants emissions (Atmosphere, Water, Soil, Waste, etc.);
- Waste storage (in situ, transport, dumps, etc.)
- Overexploitation of resources (raw matter, power consumption, water consumption, flora and fauna, etc.)
- Deterioration of the landscape (topography, vegetation, water streams, environment, etc.)
- Modification of the social, economical and cultural environment.

The CDW Recycling Process

Currently, there are no reliable references and statistics of the generation of construction waste volumes for the area of study, therefore the data were obtained from the 2010 census performed by the National Institute of Statistics, Geography and Informatics (Instituto Nacional de Estadística, Geografía e Informática, INEGI), as shown in Table 1.

Table 1. Estimation of annual generation of CDW in the municipality of Pachuca.

Year	Surface of estimated construction (m2)	Estimated generation of CDW (m3)	Generation estimated at tons of CDW (tons)
2005	138,227.11	123,022.13	98,417.70
2006	113,555.49	101,064.39	80,851.51
2007	147,365.08	131,154.92	104,923.93
2008	308,133.44	274,238.76	219,391.01
2009	169,803.53	151,125.14	120,900.12

From above table, it is estimated that only in 2009, 120.900,12 tons of CDW were generated, in average, 0.8 tons per cubic meter constructed^[8]. For this study, was taken as a reference two of the more large clandestine dumps in the area (Image 1) based on that evaluated waste composition was determined, as well as the proportions (%) for the crushing, grinding and screening^[3], as shown in Table 2, for the elaboration of the arid recycled (fine or coarse).



Image 1. Ubication of the larger clandestine CDW dump in Pachuca City.

Table 2. Composition of CDW for the study project.

Material	Composition (%)
Concrete	50
Brick	24
Block	24
Ceramics	2

The samples obtained were processed in the same way as natural stone aggregate, in order to have a comparison point. The samples were crushed with a Mercy 4x6 jaw crusher from Allis Mineral System Company to obtain a fine and a gross aggregates. The process to divide an aggregate into even size particle fractions is called mesh analysis ^[8]. The fine and gross aggregates are separated by mesh no. 4 (5mm or 3/16 in), according to the standard BS812: Part 1 (1975) and standard ASTM C-136-84 (1984). For the fine aggregate the lower limit for particle size is 0.07 mm (0.003 in). With the recycled aggregates obtained, block and concrete were designed and tested in accordance with Mexican standards NMX-C-038-1974, NMX-C-036-1983 and NMX-C-037-1986 to determine their physical-mechanical properties.

Factibility to apply the designed block and concrete as construction materials

In the construction industry, known as traditional materials exert a very strong competition in the sector (concrete, metals, ceramics, etc.). Their performances are very well known for all the figures that appear in the construction: designers, contractors, workers and even clients themselves. According to various authors, the potential growth of the use of composites in general is very high. However, this growth relies on the ability by the industry of manufacture of composite materials to adapt to the changing demands of the market. Any growth through integrating and satisfy the imperatives of sustainable development, so the appearance of the Revalorization of this material takes on a special importance ^[9]. Synthetically indicated the feasibility of application in materials commonly used in the sector of construction and tests to determine mechanical and physical properties of these materials.

- **Block tests**

Several waste composition blocks were tests. Regarding weight, the blocks elaborated with larger amounts of recycled aggregates reduced their weight in 25 to 35% in comparison with the blocks made of natural aggregates due to their density.

The best resistance behavior were presented in samples were a 50/50 proportion (recycled/natural aggregates) which passed the maximum established for 28 days in Mexican standards (Figure1), therefore in this samples it is possible to reduce the amount of cement and in consequence to obtain a lower production cost.

Regarding water absorption, the blocks with recycle aggregate presented 14.7% lower than the established in the Mexican standards.

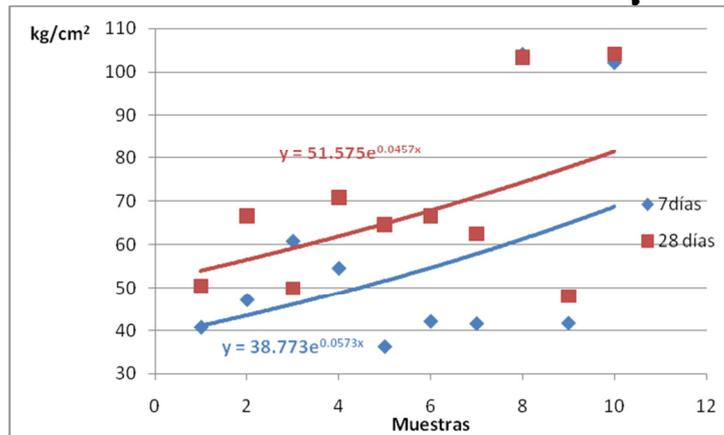


Figure 1. Block tests. Variation of resistance to breakage in kg/cm² at 7 and 28 days.

- Concrete tests

It was observed that the sample 30/70 presented a 75% resistance increase during concrete setting, whereas the rest of the samples showed a maximum of 20% increase (Figure 2). These resistance values are below the required for structural concrete, so it is indispensable to incorporate a superplasticizing additive to improve the concrete elaboration as stated in the references [2], where the effect of the additive is greater in the control concrete than in the cases in which the substitution of the recycle aggregate is 20-50%. When increasing a 0.2% the additive dose, the resistance increases up to 20%.

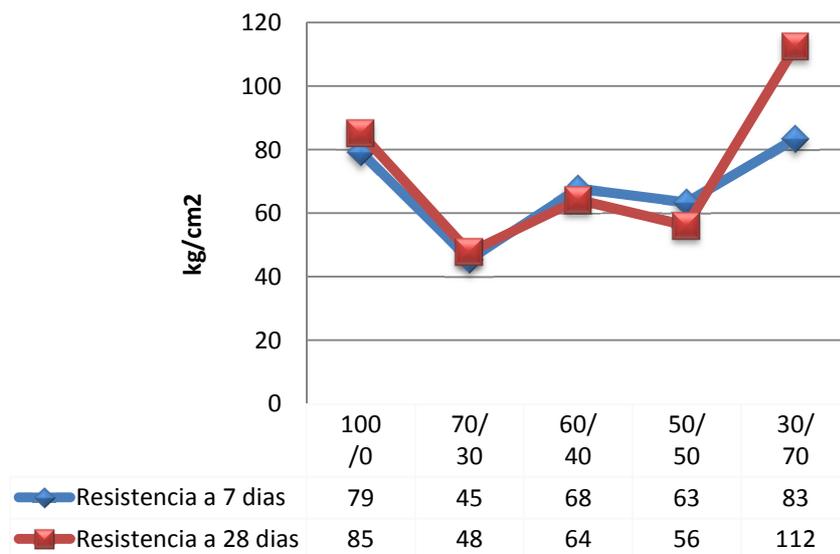


Figure 2. Concrete Test. Variation of resistance to breakage in kg/cm² at 7 and 28 days.



Conclusions

For the recycling of CDW in the area of study, the re-use of residues from ceramic and stone debris is recommended. Ceramic waste presented a more homogeneous composition and large amount of fine for being a soft material, while stone, because it is a harder material waste, presented less fine and did not allow a separation of mortar attached, giving some problems with maintenance of the mill mainly for the abrasiveness of vitrified layers of tiles and stoneware.

Overall, positive comparison results were found with Mexican construction standards and determined that the recycled aggregates, are feasible to use for making pressed blocks of concrete and concrete of low strength, same that are widely used in the area of study. Block samples, which recorded the best parameters of weight, resistance and absorption, are those corresponding to a proportion of 60/40 in added thickness (recycled arid/arid natural respectively).

In another hand, the concrete samples present a greater absorption of water. An option to balance the compressive strength, is to keep fixed the relation water total/cement. In addition, to achieve an increase in the resistance, recommended dosage of a superplasticizer additive depending on the amount of aggregate replaced to maintain the workability of the concrete. In the study where mixed recycled aggregates, with a maximum of 20% without pre-saturacion are applied, they exhibit the same features of workability, density, resistance to compression and traction than those made with recycled aggregates concrete, to the same proportion.

Finally, since showed that the recycling of mixed CDW is reusable, it is feasible to determine that, as a consequence, the environmental impact boils down to using these residues as raw material for industrial processes of building materials.

Scientific contributions

This paper develops the concept of "Mixed Construction and Demolition Waste Recycling". The application of construction and mixed into blocks of pressed concrete demolition waste is a new technical contribution that covers a niche opportunity detected within the market for recycled products.



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A Model Combining the Three Methods Lean, Green, and Six-Sigma (LG6) to Identify Waste in Construction Processes Prior to Construction Phase

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Abstract: *The construction sector is a major contributor to negative environmental impacts in the United States and furthermore consumes an abundant quantity of natural resources---. In this research, an innovative model was developed with the goal of improving the life cycle environmental impacts of buildings by identifying potential waste sources prior to the construction phase, in the earliest stages of a project. The new model, called LG6, integrates three methods - Lean, Green, and Six-Sigma.*

The functionality of LG6 is illustrated through a case study of a woodpile installation construction process. In this case study, the LG6 model identified four steps out of eight as non-value added steps according to the Lean principles. Three of the four steps involved extra time and effort by the contractor to set up equipment, while the fourth involved additional work that could have been avoided with adequate planning. For the case study, the LG6 model showed that environmental impact could be reduced by 9%—and expenses reduced by 1% as well—if alternative processes had been implemented.

Keywords: *Construction Industry, Improving construction processes, Lean Construction, Life cycle assessment, Six-Sigma.*

1. Introduction

Activities related to the construction industry have a considerable environmental impact in the United States: Total construction and demolition (C&D) waste in the US was estimated to be 325 million tons in 2003¹. Unfortunately efforts to reduce C&D waste have not been very successful to date. One reason for this is that while contractors have different methods of completing their jobs, usually relying heavily on their own experience, for most, success is defined as finishing the job within the given constraints of money, time, and quality sometime. Although contractors may typically finish within the budget and the time frame they are given, their construction methods may generate a significant amount of waste².

Another reason it is difficult to reduce waste in the construction process is that the nature of the construction industry is complicated: every project is unique and has a different purpose³.⁴ This fragmented nature of construction makes the likelihood of waste being generated at



any point of the project phases greater. Therefore, it seems that environmental and economic benefits arising from the reduction of waste can best be achieved by proactively planning ways to prevent waste from being generated in a project in the first place *a priori*, rather than simply seeking to reduce it *ad hoc* on site during construction itself⁵.

This paper presents an innovative *model* for the identification and minimization of waste and extends a previously developed conceptual framework⁶ by applying three proven methods at the *pre-construction bidding/planning phase*. The developed model can be applied to many construction processes without the need for trying new tools every time we evaluate a construction producer while the framework was developed with the capability to apply certain aspects that might differ from one process to another depending on the chosen process.

This present work applies Lean, Green, and Six-Sigma (LG6) methods to enable contractors to proactively identify and eliminate potential waste *prior* to the construction phase. The hypothesis is that LG6 will reduce waste generation during the pre-bidding and bidding phases of construction projects, resulting in both decreased environmental impacts and lower costs. All three methods can be efficiently integrated into the project pre-construction phase: Lean to identify waste, Green to evaluate the environmental impact of potential waste, and Six-Sigma to evaluate and improve process performance. The objectives to achieve by developing the LG6 model are:

- 1) Decreasing the overall environmental impacts and carbon footprint and increasing the efficiency of the construction processes.
- 2) Increasing awareness of green initiatives and the value of their application to the construction industry.
- 3) Creating a tool that would help buildings awarded LEED points under innovation & design process category.

2. Research Methodology

The work consists of developing a proactive model and executing a case study to examine the validity of the LG6 model. Excel, a well-known and easy-to-use software tool, was used to construct the LG6 case.

2.1 Lean Green Six-sigma (LG6) Model

The LG6 model has two parts (Figure 1): *Level one*: contains the basic information about the construction process under consideration, including the name, scope of work, date, client information, and project requirements. Some main points about the three methods Lean, Green, and Six-sigma are listed at Level One of the LG6 model, where it is essential to give the user a reminder of what the purpose of each method is. *Level two*: Divided into five functions including Define, Measure, Analysis, Improve, and Control (DMAIC).



The installation of woodpiles process														Start	Finish						
Scope of Work:																					
Level 1																					
(D) Define			(M) Measure			(A) Analyze						(I) Improve	(C) Control								
						Lean		Green	Environmental Impact Categories												
Start Date	Process Steps	Units	A- Materials	B- Equipment	C- Workers	Value added step	Non-Value added step	Source of impact	1	2	3	4	5	6	7	8	9	Alternatives with less potential impact	Total # of Steps	Total # of non value added Steps	DPMO
D-1-			M.1.A-	M.1.B-	M.1.C-	*		A.1-										I.1-			
D-2-			M.2.A-	M.2.B-	M.2.C-	*		A.2-										I.2-			
D-3-			M.3.A-	M.3.B-	M.3.C-	*		A.3-										I.3-			
D-4-			M.4.A-	M.4.B-	M.4.C-		*	A.4-										I.4-			
Total duration HRS:			Total cost \$:					Total emissions:													
Non-value added duration HRS:			Total cost for non value-added steps \$:																		

- Keys Legend:**
Environmental Impact Categories:
 1: Global Warming potential (CO₂)
 2: Acidification Potential (H⁺moles)
 3: Carcinogenics Potential (benzene eq)
 4: Non-Carcinogenics Potential (toluene eq)
 5: Respiratory Effects Potential (PM_{2.5} eq)
 6: Eutrophication Potential (N eq)
 7: Ozone-Depletion Potential (CFC-11 eq)
 8: Ecotoxicity Potential (2,4-D eq)
 9: Smog Potential (NO_x eq)

Figure 1 Outline, LG6 Model

2.2 Case Study

A case study of the pile-driving process was generated to illustrate the functionality of the LG6 model. Specifically, the model was used to evaluate the process for furnishing and driving 168 woodpiles that were 40 feet long, 14 inches in diameter at the base and 7 inches at the tip into normal soil. This case study was taken from a project completed by a local contractor for a commercial building project in Pittsburgh, PA-USA. The contractor provided all data regarding the cost of the construction process including.

3. Research Findings and Results:

Define (D): For the sample case, a total of eight steps and 88 hours were estimated to finish furnishing and driving 160 woodpiles. The identified steps were: delivering the materials to the site, driving the equipment to the site, setting up the equipment, taking down the equipment, moving out the equipment, driving the piles, cutting to length, and cleaning up the site. The step of driving the piles was the most time-intensive, using 56 labor-hours; while cutting to length was second, requiring 16 hours of work (see Table 1).

Table 1 Define phase explains start dates, process steps and units for the woodpile installation process.

Define (D):



Date start	Process steps	Process Description	Value
06/01	D.1	Delivering the woodpiles and the pile points to the job site	Distance: 50 miles
06/01	D.2	Driving the equipment to the job site	Distance: 30 miles
06/02	D.3	Setting up the equipment	Duration: 4 hrs.
06/02	D.4	Taking down the equipment	Duration: 4 hrs.
06/02,03	D.5	Moving out the equipment	Duration: 4 hrs.
06/04	D.6	Driving the piles	Duration: 56 hrs.
06/12	D.7	Cutting to length	Duration: 16 hrs.
06/14	D.8	Cleaning up the site	Duration: 4 hrs.
Total Process Time Duration in Hours			88
Non-Value added Total Time Duration in Hours			28
Non-Value Added Step		Value-Added Step	

Measure (M): The next stage required an assessment of all resources consumed by each step in the construction process, including materials, equipment, and workers (Table 2).

A- Materials: Quantities and Cost: Only step D.1 “Delivering the woodpiles and the piles points to the job site” was estimated to consume significant quantities of materials: about 6720 ft. of woodpiles, and 160 steel pile points at a total cost of \$83,795.

B- Equipment: fuel usage, and equipment cost: Both step D.1 “Delivering the woodpiles and the piles points to the job site” and step D.2 “Driving the equipment to the job site” was estimated to require trucks to deliver the materials (50 miles away) and the equipment (30 miles away) to the job site. The delivery costs for materials and equipment was estimated to be included by the vendor in their respective costs. Step D.6 “Driving the piles” was estimated to require equipment use representing a total equipment rental cost of \$6859 and consuming a total of 4711 gallons of fuel. Step D.7 “Cutting to length” was estimated to use a power saw costing \$523.60 for rental and consuming about 6 gallons of fuel.

C- Workers: no contractor workers were required for steps D.1 “Delivering the woodpiles and the piles points to the job site”, and D.2 “Driving the equipment to the job site”; however, the remaining steps in the process each did. Step D.6 “Driving the piles” required a crane operator (at a higher hourly rate) in addition to general laborers. The total cost for the workers for this process was estimated at \$5371.

Table 2 Measure phase explains consumed resources for the woodpile installation process, including materials, equipment, and workers

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Measure (M):				
Process steps	Materials (A)	Quantities	Unit cost \$	Total cost \$
M.1.A	1. 160 wooden piles (40 lin. ft.)	6720 ft.	11	72912
	2. Pile points	168 pieces	65	10884
Total Materials Cost				83,795
Total Materials Cost for Non-Value Added Steps				0
	Equipment (B)	Fuel usage in gal.	Cost of equipment usage	
			Unit cost \$	Total cost \$
M.1.B	1.A Truck for materials transportation	Include with materials cost		
M.2.B	1.A Truck for equipment transportation	Include with equipment cost		
M.6.B	1. Crane 800 HP. Diesel	2688	82.4	4614.4
	2. Leads for hammer	NA	14.63	819.28
	3. Pile hammer 600 HP. Diesel	2016	10.8	604.8
	4. Air compressor 3.0 HP. Gasoline	6.72	14.65	820.4
M.7.B	1. Concrete saw, Gasoline 5.6 HP.	5.4	9.35	523.6
M.8.B	1. Construction cleaning tools (brushes, brooms, etc.)	NA	NA	NA
Total Equipment Cost				7,382.5
Total Equipment Cost for Non-Value Added Steps				523.6
	Workers (C)	Working Hours	Unit cost \$/hr.	Total cost \$
M.3.C	1. (2) General laborers	4	15.56	124.48
M.4.C	1. (2) General laborers	4	15.56	124.48
M.5.C	1. (2) General laborers	4	15.56	124.48
M.6.C	1. (1) Crane operator	56	21.67	1386
	2. (3) General laborers	56	15.56	2987.52
M.7.C	1. (2) General laborers	7	15.56	497.92
M.8.C	1. (1) General laborers	1	15.56	15.56
Total Workers Cost				5,370.2
Total Workers Cost for Non-Value Added Steps				871.4



Analyze (A): Each step of the woodpile installation process was then evaluated according to Lean criteria to determine if it added value and by Green criteria to calculate its environmental impacts in each category (See Table 3).

Lean: Four steps out of the total eight were recognized as non added-value steps, namely Step D.3 “Setting up the equipment”, Step D.4 “Taking down the equipment”, Step D.5 “Moving out the equipment”, and Step D.7 “Cutting to length”. Cutting to length is a task that is responsible for the kind of materials residual waste typically found in most of the construction projects reported by EPA 2010 (U.S. Environmental Protection Agency 2004).

Green: By applying Life Cycle Assessment it shows that two major sources of potential environmental impacts in this process were identified: First the estimated materials —both wood and steel—have significant environmental impacts. Wood shows the highest aggregate impacts in categories such as Carcinogenics, Respiratory effects, Eutrophication, Eco-toxicity and Smog; while steel reflects greater impacts in the categories of Global Warming, Acidification, Non-carcinogenics and Ozone depletion. A second major source of impacts was fuel usage for both transportation and equipment operation. The crane operation was the highest contributor to Global Warming Potential while driving the piles ranked second (see Table 3).

Table 3 Analyze phase highlights value-added and non value-added steps and addresses environmental impact of the woodpile installation process.

Analyze (A):				
Lean			Green	
Process Steps	Value-Added Steps	Non Value-Added Steps	Source of Potential Waste/Environmental Impact to be Analyzed by LCA	Inventories
A.1	✓		A.1.1 Resources usage / Wood	6720 ft.
			A.1.2 Resources usage / Steel	2016 kg
			A.1.3 Transportation/ Diesel	50 miles
A.2	✓		A.2 Transportation/ Diesel	30 miles
A.6	✓		A.6.1 Equipment usage/ Diesel	2688 gal
			NA	NA
			A.6.3 Equipment usage/ Diesel	2016 gal
			A.6.4 Equipment usage/ Diesel	6.72 gal
A.7		✗	A.7 Equipment usage/ Diesel	5.4 gal
A.8	✓		NA	



Green - Life Cycle Environmental Impact Categories									
Item	Global Warming (CO ₂ eq.)	Acidifica -tion Potential (H+moles eq.)	Carcinog -enics Potential (Benzene eq.)	Non- Carcinogenics Potential (Toluene eq.)	Respirato -ry Effects Potential (PM _{2.5} eq.)	Eutrophicat -ion Potential (N eq.)	Ozone Depletion Potential (CFC-11 eq.)	Eco toxicity Potential (2,4-D eq.)	Smog Potential (NO _x eq.)
A.1.1	-1065098	93808.84	98.9	970641.3	315	39.6	2.81E-06	20099.9	1279
A.1.2	2116	1044	62	110759	4	0.6	7.0825E-06	249	10
A.1.3	65	23	0.012	195	0.05	0.04	9.6911E-06	9	0.5
A.2	39	14	0.007	117	0.03	0.024	5.8146E-06	5.4	0.3
A.6.1	4683	3227	11	239336	5	2	1.3081E-06	6646	32
A.6.2	NA								
A.6.3	3512	2420	9	179502	4	1.7	9.8109E-07	4985	24
A.6.4	13	8.8	0.03	651	0.01	0.006	3.5594E-09	18	0.09
A.7	10	7	0.02	520	0.01	0.004	2.8444E-09	14	0.07
A.8	NA								
Total Emiss -ions	-1054660	100552. 8	181.2	1501721.5	327.6	44	2.7696E- 05	32027.3	1345.7

Improve (I): Alternatives were generated and discussed with the contractor to replace the previously proposed steps in order to improve the environmental performance of the process (See Table 4). It is not necessary that each step be replaced with a more efficient, environmentally friendly or less costly alternative; rather, the objective was to consider another alternatives might be applied to reduce environmental impacts and improve the bottom-line. For instance, renting equipment or acquiring material closer to the job site could reduce fuel consumption, thus lowering costs and emissions.

Table 4 Improve phase discusses alternatives to the process with less environmental impact and better economic returns for the woodpile installation process

Improve (I):	
Process Steps	Optional Alternatives (For better process performance)



I.1.3	Purchase materials from a close providers (Less travel distance)
I.2	Rent equipment from a close providers (Less travel distance)
I.7	Consider wood piles with same length

Control (C): This stage evaluated via Defects Per Million Opportunities (DPMO) the revised method the contractor actually implemented to finish installing 168 pieces of woodpiles. According to the Lean criterion, four out of the eight steps (50%) in the process were considered non value-added steps; because of this, the current contractor method performance would create 500,000 defects in every million attempts. On the Sigma metric this performance is equal to 1.5.

Table 5 Control phase explains the current performance level according to the Six-Sigma scale for the installation of the woodpile process

Control (C):		
Total Number of Steps in The Process	Total Number of the Value-Added Steps in The Process	Sigma Metric
8	4	1.5

4. Conclusion

This research study seeks to create an innovative yet intuitive and easy-to-use model that can help improve environmental performance and bottom-line results of construction processes.

For this purpose of preventing waste, a pro-active Lean-Green-Six Sigma improvement model (LG6) was designed to help contractors and process owners to re-evaluate their traditional construction methods during the bidding phase to decrease environmental impacts, inefficiencies and costs. In order to illustrate the LG6 model, a case study of installing 168 of woodpiles was examined. The LG6 shows that the costs could be reduced by 1% and greenhouse gas emissions by 9% if the original process of wood piles was revised to implement more environmentally friendly alternatives.

The case-study results in terms of savings might seem insignificant, yet the woodpiles process is only one construction process that is often integrated with other non-optimized processes. Evaluation of all of the steps in a project, then, and use of alternatives suggested by LG6 could result in more significant aggregate savings in money, time, and environmental impacts.

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^{vi} See: <http://www.flaska.eu/less-waste-2>

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Session 97:

The role of the 'other' stakeholders. How to improve the position of the weakest members of society in empowerment processes?

Chairperson:

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Assoc. Prof. Architecture and Urban Design, The German University in Cairo (GUC)



Ecómetro, collaborative work project to develop a design and measure tool of ecology in architecture

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***Abstract:** The systems for evaluating and certifying of buildings have recently become important tools in the quantification of environmental impacts caused by the construction, demolition and use of buildings in our environment.*

There are many different evaluation systems that differ in the complexity of use as well as the different variables of study. However, we still face barriers and gaps in the environmental evaluation systems and sustainability of the buildings which complicate the application of this systems in a bigger scale: Most of the methodologies are subject to copyrights and require the payment of different royalties/licenses for their use; this in addition of the fact that in most of the tools there are certain opacities in the process of the definition of the methodologies/criteria (regarding the right of use and exploitation) which restricts the participation and the use recursively.

We will present the experience gathered from applying the best practices and know-how of open source communities to the process of building a new tool for environmental evaluation: the Ecómetro

Open source, collaborative work, software tool, ecology, architecture, and community

State of the art

Currently, the impact and importance of the energetic efficiency of the buildings in the global sustainability are well known and commonly accepted. It has been estimated that nearly the 40% of the global consumption in Europe is due to the building area and it represents 1/3 of the CO₂ emissions¹. In addition it is calculated that more than 50% of the raw materials extracted from the earth are transformed in materials and products in construction². The construction of new buildings and its operation suppose the 16% of the water consumption in the world³.

On the other hand, the importance of the construction sector is not only measured by the environmental impact. At social levels, the construction practices also affects other key social factors linked with the quality of life of the citizens.

The evaluation and certification systems have lately become an important tool of quantification for the environmental impact caused by the building, demolition and use of the

buildings. Recently it has appeared an important number of evaluation methodologies of sustainability at a global, European and national level. There is a wide range of different



evaluation systems that varies in their usability as well as the accuracy, thoroughness or number of variables used. As different examples we could mention the following: LEED (Leadership in Energy and Environmental Design), BREEAM (Building Research Establishment Environmental Assessment Methodology), GBTOOL or DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen).

Nevertheless, even though these methodologies are aimed somehow to the way of identifying the sustainability of different buildings, there are still some unresolved issues that make it impossible to make a comparable, precise and full evaluation of the sustainability of the buildings.

The Open House project (FP7⁴) indicates as the main lacks and obstacles:

- There is no European standard for sustainability edification. The current regulations regarding sustainability are currently under development, not being fully covered in all its aspects.
- There are several aspects that are unresolved in these methodologies regarding the accessibility, the weight of each indicator in the methodology depending on the priorities and distinctive feature in each country. Examples of these indicators are the type of the building, the type of the user and the weather. This unresolved aspects should be important for the political agenda of each country.
- Most of the methodologies are subject to copyrights and require the payment of fees in order to use it.

From our point, these topics should also be covered:

- These privative systems restrict the participation along the definition process of the methodology. And in most of the cases, these closed systems do not provide information regarding the used criteria, as well as the weights assigned to each indicator.
- Give more weight to the ecology in the process of the building, not only in the final result. An example of this can be seen in some of the certification system with their different certification levels, such as *Silver, Gold and Platinum*, according to the score of the building.
- This can also be extended to the idea of having a certification that does not evaluate the final product but that introduce the ecologic perspective in the design process from the beginning.
- The knowledge required for attaining this certification has associated a considerable price.

From the above we can conclude that is urgent to find new ways to share the knowledge that guarantee the environmental implications of a project. This is the aim of the present text.

Translating culture open source to ecómetro project. Experiences team

"The implications and ramifications of open source software made researchers on other fields



realize that this techniques and philosophy could be applied on their respective fields, even though there were not directly related to software development. The architecture was one of these fields." [Pérez de Lama, Guitiérrez de Rueda, Sánchez-Laulhé y Olmo Bordallo, (2011)⁵].

For the case of the design and develop of a design and evaluation tool for the ecology in the architecture, the philosophy of open source could have been applied strictly for the source code. However, we realize the benefits of applying this open culture to the way of work as another element, included as a standard.

"The translation of the concepts of "Open culture" to the field of design and architecture is not immediate, it poses multiple levels and alternatives". [Pérez de Lama, Guitiérrez de Rueda, Sánchez-Laulhé y Olmo Bordallo, (2011)⁵]. Authors have discovered that the exercise of these "freedoms" requires a constant retrospective in each of the parts integrated in the project. This retrospective must be focused to serving accessibility, involvement, publishing capacity and distribution.

In 2011, Satt Architecture office [<http://satt.es>] got in contact with Montera34 to start the development of Ecómetro [<http://ecometro.org>], "an open source tool for measuring and cross reading of the ecology in the process of design, build and use of the buildings, which quantifies the impacts on the Earth as well as on the ecosystems and the human health". It is basically is transparent and editable tool associated with an open certification system. This was the starting point of an experience, which is still ongoing. We are going to present the advances that were done, organized in five areas⁹.

Creating a movement and a common structure

After several sessions of joint work between Satt, and Domenico Di Siena [<http://urbanohumano.org/agency>], Montera34 and other developers (node Developer Network), the first decision made was to start working while in parallel a creation of a Community will be done.[Sánchez, 2013]⁷

A working structure was created in order to allow distributed working, through which facilitate the participation on the project to all who may be interested. This allowed some importance on the tool, which at first seemed like the center of the project. But then authors realized that the most important issue was to work with potential people interested in use a tool like that would be the Ecómetro.

A key issue of the tool is that the process of defining the indicators and their weights should be an open process. It was necessary to bring the technical knowledge to the community concerned in order to let anyone interested to participate in the design of the evaluation criteria. Thus, it was in this period were the "Ecología a Debate" (discussion sessions) spring forth. After this discussion sessions, indicators workshops was the next step; that help to



understand the difficulty of reaching a consensus from the ecological perspective. In January 2014, the forum was opened. A direct communication channel between users (professional building sector and students) and the scientific community.

After a year of working on the software tool, Ecómetro Association was founded.

Ecómetro association was born as a Common structure that articulates all the tools, resources, and activities to serve the community.

Conception of open systems

As mentioned above, a fundamental shared question was that the indicators definition process and their weight should be an Open process. Everyone who is interested can participate in the design of the evaluation criteria. This means not only developing a program that would allow editing, and opened the design process to all interested community. This allows you to define the evaluation criteria collectively. This is one of the longest processes that were faced.

In the same way, the testing process of the first version tool was opened to the community. This process involved different actors that allowed us to reach the Beta version, a stable version. And it is presented today in WSB14.

Creating tools and resources to share knowledge.

Ecómetro Software tool is Open Access and free. This means that anyone can use it within the ecometro.org platform, but also, if necessary, clone, modify and use it independently.

Perhaps one of the most important decisions that we have taken was moving from a measure tool to a design tool.

One of the main barriers found, it was translating the complexity ecological perspective to professional practice. Ecómetro, software tool, was going to be a self-assessment tool. Each of the steps that shape the tool matches the steps of the design process on architecture professional practice starting with the Mapa de aproximación⁸.

Not only in the software tool; but also have created different activities (discussion sessions, workshops, operating manual, glossaries,...), all properly documented and accessible to people who want to approach.

Design of distribution licenses

In the introduction of this paper, several certification tools on the market were seen. They are



mostly privative payment prior-use tools.

Ecómetro software tool takes into considerations, like main methodology, the use of all specific local conditions and life cycle analysis [ACV].

For ACV is necessary to use environmental impacts database. At present there is no single environmental impacts database. And the most highly rated databases have use rights. How to incorporate a database licensed under copyright, which prevents its use by third parties?.

Finally we work on our own database based on general database, avoiding problems associated with copyright of privative databases.

One of the greatest achievements is being carrying out the creation of this database of common environmental Impacts. La Oficina de Cambio Climatico [OFCC] has been aware of the need for the existence of a single database for the development of sustainable buildings and it is promoting a national consensus to establish a single construction materials database Related to environmental impact information.

The organization of collaborative systems

Ecómetro, tool and association, is a complex project. The organization of the several collaborative systems requires different strategies, which depend on the type of work and stakeholders. Enunciate three of the practices employed:

1. Divided in steps. As indicated above, one of the key points are the Ecómetro is the collective definition of the evaluation criteria. To achieve this goal we have established different phases in order to solve the different difficulties that hinder progress. First the establishment of the community of users interested in the project; second, the creation of sub-communities specific to particular interest inside the project (developers, people interested in the definition of the environmental indicators, translators, etc.); third, the creation of the documentation; forth, the creation of distribution channels for the documentation.
2. Iteration. The tool development phases, lets go nurturing with input from the community through successive approximations to the solution; starting from an initial estimate. Each phase is a step with clearly defined objectives, and is conceived independently in terms of resources, time and process. At the same time, each phase insert a general workflow. We could say that this iterative develop answers to a fractal structure, in which each phase has the same



structure of the project. Inside each phase we have sub phases, organized as demanded, always with the same unit structure as their parent phase.

3. Bidirectional exchange of information system. The different channels of exchange of information are in fact channels of exchange of information organized by areas.

The Experts publish their research in their area (for instance, the developers publish how to use the tool) and the non-experts the feedback of use. This way, the binomial expert-user is broken in order to become an expert-expert, each on their respective field. Moreover, these channels allow the exchange of knowledge between different areas of the project. This way, the people that actually are using it design the tool.

An example might be the introduction of social indicators in the Ecómetro- tool. Initially, it was ruled introduce social indicators, because there was enough complexity to the definition of environmental indicators.

Testing phase of alpha version was opened to the community while the discussion sessions around the ecology were held.

During the discussion sessions, the community highlighted the importance of introducing social indicators. The community mobilized. Has been drafted and is being studied and how to introduce the social setting in the tool. Including changes to the beta version. A way of work on continuous improvement.

End Notes

The international community recognizes that the green economy is an essential strategic tool for sustainable development. Beyond the trend, we propose several considerations that have emerged as a result of the work we are doing while developing the tool. Some of these considerations are:

1. Each of our projects should incorporate an environmental perspective. It should be mandatory to face the economic growth against the consumption of natural resources. We need a common agreement at EU level on which the concept of sustainable building should resolve technical issues between different methodologies. Fundamental aspects allow us to act with rigor; measure, compare, configure and communicate.
2. It is desirable to facilitate the access and the dissemination of knowledge, including scientific knowledge, as a way to improve society as a whole, and to encourage the development and collective learning. This should include ways to introduce an ecological perspective in the design building process. Facing some methodologies and scientific or academic institutions, it is necessary to adopt a different way to do that emphasizing knowledge as a "Common Good" by the community.



3. The opacity of some organizations, certification systems or methodologies, is an intentional exclusion to sustain business models around the "new green market." These models are based on trade occurring under copyright or proprietary-license. We are at a point where is possible to create a benefit market (services market), not related to copyright-strategies.
4. Note that it is necessary to implement the use of new licenses that opposes the traditional copyright, in order to facilitate access to knowledge, the content modification and the distribution to the community, provided that the resulting product remain free. Copyright and patents interfere with the diffusion of knowledge.
5. Thanks to the Internet, we have found that a small action with many followers bring great changes, like for instance, a community mobilized against traditional hierarchical structure. The adoption by the community to a different way of thinking as it might be the Open Culture, empowering every member. Every hand will count. Each member of the community concerned will provide building support that allows collaborative content. The community itself will manage its care and maintenance, thus reducing costs and ensuring the future of the tool.
6. Technological development enables the development of inclusive tools with different levels of accessibility, from everyday use to the most technical. Forms of collaborative work, together with free open tools allow professional and customers to work together. This kind of processes brings together the research world and the professional practice (in the best case, including the end user), allowing the exchange of information in both directions. Top-down and Bottom-up.
7. In such complex systems, where the process requires the participation of different actors, the development of "free" tools is a necessary but it is not a sufficient condition. We need "Open" tools and ways of making them, in order to facilitate interaction and create the structure and knowledge. Living processes to serve the community.

Final Discussions

Ecómetro criteria metrics are public and anyone interested can participate in its definition. On the other hand, the code of the tool is open source, which is available to anyone under the GPL license. The possibility to modify the code and the criteria of the metrics makes the certification system useful and versatile. This allows the application of the tool to architectures in any place of the world, affected by environmental factors totally different, built with different materials and subject to different regulations [Sánchez, 2013]⁷. These are fundamental keys to cross reading of ecology and design of our buildings. Adopting these values and ways of making, so close to the ecological vision of caring for the environment, is itself the objective of the ecómetro. Ecómetro does not aspire to be a certification system, but a process of learning the relationship of ecology in architecture.

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4. *Open House-FP7, (2013). Metodologías para la evaluación de la sostenibilidad en edificios. www-openhousefp7.eu*
5. Pérez de Lama, Guitiérrez de Rueda, Sánchez-Laulhé y Olmo Bordallo, (2011). *Fabricación digital, código abierto e innovación distribuida. 4ª Jornadas Internacionales sobre Investigación en Arquitectura y Urbanismo.*
6. Freedom to use the program, for any purpose, freedom to study how the program works and modify it, adapting it to your needs; freedom to distribute software- copies, which can help your neighbor, and finally freedom to improve the program, and release those improvements to others, so the whole community benefits thereof. (Freedoms 1 and 3 require access to source code because studying and modifying software without its source code is highly impractical).
7. Sánchez Uzábal, A. (2013). *Diseño colaborativo: abriendo el proceso de diseño. +mas D, Revista Digital de Diseño. ISSN: 2027-095X*
8. The Mapa de aproximación is a concept refer to the first step in the design process. We have developed this concept in our architectural office. The Mapa de aproximación is the first step in creating a real relation with the local environment. In this step we analyze the environment, add to the local conditions that affect the project: climatic characteristics, raw materials, configuration of the natural environment, local suppliers, ... and generate an map fully information over we draw the project. The Mapa de aproximación is one of considerations in our Code of Good Practice guidelines inside our professional practice in the architectural office.
9. In his anthropological study of the development process of the Ecology of Free Software and Open Source, between 1970 and 2000, Kelty (2008) points out these 5 areas that transcend technical and scientific issues. These areas should be taken into consideration for generate a similar ecology into architectural and design field.

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Good Urban Governance of Informal Settlements in Metropolitan Areas: Case Study of the Informal Settlement of Ezzbet Al-Haggana, Cairo-Egypt

Authors:

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Abstract: *Urban Governance of Informal Settlements in Cairo has become a critical challenge facing the Egyptian government Identification, integration and collaboration of relevant stakeholders becomes crucial. Consequently, this research aims at investigating new and adjustive governance models that imply effective participation of stakeholders. Three Methods were utilized; literature review to investigate norms of good urban governance and informality. Afterwards, political transitions in Egypt were traced in correspondence to spread of informal settlements in Cairo. Finally, the informal settlement of Ezzbet Al-Haggana in Cairo is particularly studied, as live evidence on the absence of collaboration between different stakeholders in a responsive framework. Site visits and interviews were conducted at this latter stage, which will be further explained within the paper. The research ends up with a conclusion that formal sector is incapable of providing adequate housing and services to everyone independently. Thus, all relevant actors should collaborate in efficient governance model.*

Keywords: *Good Urban Governance, Metropolitan Area, Informal Settlements, Egypt, Cairo, Ezzbet Al-Haggana*

Insight on Governance and Urbanism: Conceptual Framework

The term governance was literally introduced for the first time in 1989 during The African Study for Sub-Saharan countries as “*the exercise of political power to manage a nation’s affairs*” (Maldonado, 2010). The United Nations Development Programme provided in 1997 a more explicit definition for governance as “*The exercise of economic, political and administrative authority to manage a country’s affairs at all levels. It comprises the mechanisms, processes and institutions, through which citizens and groups articulate their interests, exercise their legal rights, meet their obligations and mediate their differences.*” (The world Bank, 2013). In this respect, the United Nations for Economic and Social Commission for Asia and the Pacific UNESCAP identified characteristics for governance to be good. Subsequently, the United Nations Centre for human Settlements UNCHS proposes set of indicators to measure the success of Governance within the urban context. The following diagram brings the two frameworks together as shown (see figure1), where the good governance would act as a trigger (Cause) for better urban performance (Effect).

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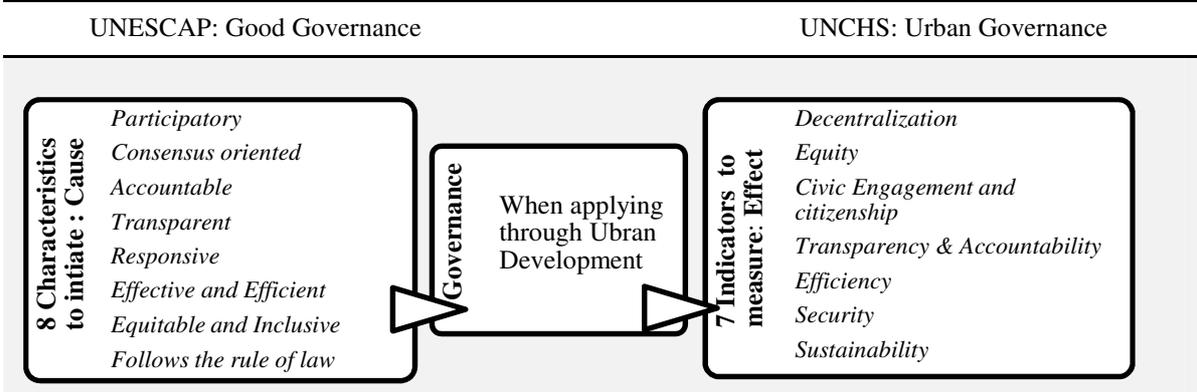


Figure 1 co-relationship between UNESCAP 8 characteristics of Good Governance and the UNCHS 7 indicators used to measure the effectiveness of the process in the Urban Context (Authors)

In order to achieve successful governance process, the voices of different actors should be represented even the most vulnerable groups. Thus, there should be a preliminary step for ‘Stakeholders’ identification’ in relation to any proposed urban development, even if some of these groups could have non uniform preferences (Rai, 2004). Subsequently, there is always a common classification of actors under three main groups illustrated as follows in Figure 2

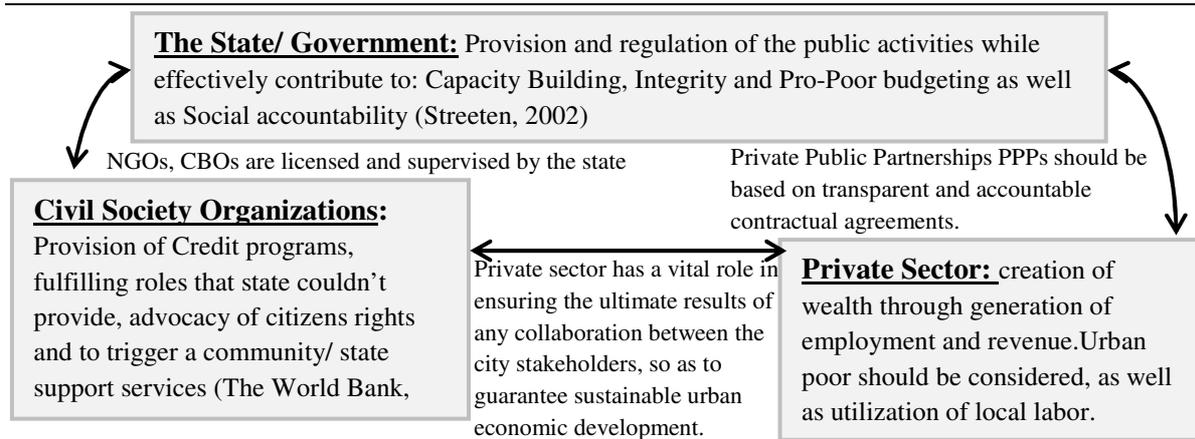


Figure2 shows the cross relations between three main stakeholders within the urban context (Authors)

In light of the previous diagram, these interactions and roles should be defined and questioned accordingly within different urban development stages.

Urban Informality in Metropolitan Cities⁴

There are 200,000 of Informal communities around the world, most of them in or around cities (United Nations for Human Rights), in which UN defines the Informal settlements as: “1. areas where groups of housing units have been constructed on land that the occupants have no legal claim to, or occupy illegally; 2. Unplanned settlements and areas where housing is not in compliance with current planning and building regulations (unauthorized housing)” (UN-HABITAT, 2007). According to UN-habitat the informal Settlements term is

⁴ The general concept of a ‘Metropolitan Area’ or ‘Metropolitan City’ is that of a core area containing a large population ‘nucleus’, together with adjacent communities that have a high degree of economic and social integration with that core (Bahl, Linn, & Wetzal, 2013)



usually associated with the urban poor, who have no other alternatives for getting a shelter except in a deteriorated and illegal context.

Inhabitants of such settlements suffer from shortage of basic urban services and limited life chances; some of them are not able to obtain formal-sector jobs due to their weak social and educational capacity. Hence, these informal communities are physically isolated from the rest of the formal administrative units in addition to social class significance (UN-Habitat U. N., 2003). Thus, certain reforms should be set towards integration of all stakeholders within the existing urban governing system; so as to increase chances of such informal communities for better living conditions.

This will be investigated below in Egypt, in which informal settlements are considered to be the dominant mode of urbanization, spreading on urban fringes, either on privately-owned agricultural land or on state-owned land in desert areas.

Transitional Political Influences on Urbanism in Cairo

Governance of Metropolitan cities such as Cairo is subjected to global trends and changing ideologies, in which around 60 percent of Metropolitan Cairo’s residents live in informal settlements, (Sims, 2011). In light of this percentage, one can relate the Greater Cairo’s political and economic transitions to its present urban configuration and the spread of informal settlements. This argument is further classified into time frames below in table 1

		National Policies	Urban Reflections	Informality
1952-1967	“The Republic Declaration”	Nasser’s Regime: Socialism and the Industrialization policies were embraced by the new governing powers in Egypt.	The first master plan of Cairo (1953-1956), in which Six satellite industrial zones were proposed to receive 50 % of the investments	Expansion on agricultural land as their sale for building was more remunerative (Al-Kadi, 1987). First informal occupancy was by the state in Manshiet Nasser to relocate people from slums in Al Drasa and Al Azhar. (Sims, 2011).
1967-1973	”The Transition” from Nasser to Sadat:	After Nasser’s Death in 1970, Anwar Al-Sadat succeeded him in the presidency. In 1971. Egypt had a new Constitution towards a powerful parliament and new legislations ⁵	Late 60s there were Public Evacuation from Suez Canal cities due to ‘Egypt-Israel’ war	Internal migration; around one million people to be in Cairo in Manshiet Nasser (Sims, 2011). At the end of 1960s Nasser ordered to extend water and power for them.

⁵The 1971 Constitution remained in force - with few amendments in 1980, 2005 and 2007 – until its dissolution in February 2011.



Post 1973 -1980	“The Victory, Peace and Aspirations”	Sadat launched economic policies of “ open door policy ” or “Infitah for “gradual economic liberalization”. Hence, land prices skyrocketed (Sejourne, 2009)	In 1977 “ New Towns ” policy was proposed to relocate the buildings growth on agricultural land into public housing on the desert fringes of the city.	Most of these new towns were not successful to grab inhabitants and informality just kept spreading (Sejourne, 2009).
1981 -2011	“The Stabilization”	Mubarek Regime: This time has witnessed Capitalism and privatization of public sector.	First appearance of upper class segregated desert compounds (Cairo Observer, 2011). On the other hand low income and urban poor found themselves obliged to live in low cost informal housing . Proposing Cairo 2050 project in an attempt for displacement of informal inhabitants all over Cairo	Egypt’s Planning Law No. 3 of 1983 prohibit local authorities from connecting infrastructure to illegal housing units (World Bank, 2007).This law was formally violated to accommodate the needs of informal inhabitants and grab them politically . In 2008, Establishment of the Informal Settlement Development ISDF⁶ after the collapse of the unsafe cliff of Al-Dwika in Cairo, and the death of many informal inhabitants (isdf.gov.eg, 2008).
2011 -Present	“The Public Revolution”	Egypt has witnessed a public uprising on the 25th of January 2011 for more democratic reforms , since then two presidents (Mubarek and Morsi) were ousted by the military and two constitutions were cancelled. Former Elected councils were dissolved (Two Parliament , local popular councils) ⁷		Absence of updated Urban framework in which Informal settlements exponentially Expanded after the revolution. Lack of law enforcement due to absence of Police role against thugs and informal contractors.

Table1: Brief on National Policies since 1952 and Its Urban Reflections (Authors)

It can be traced through previously mentioned national policies and reforms that urban development is not being thought of as an independent component of city, but more to be economically and politically biased.

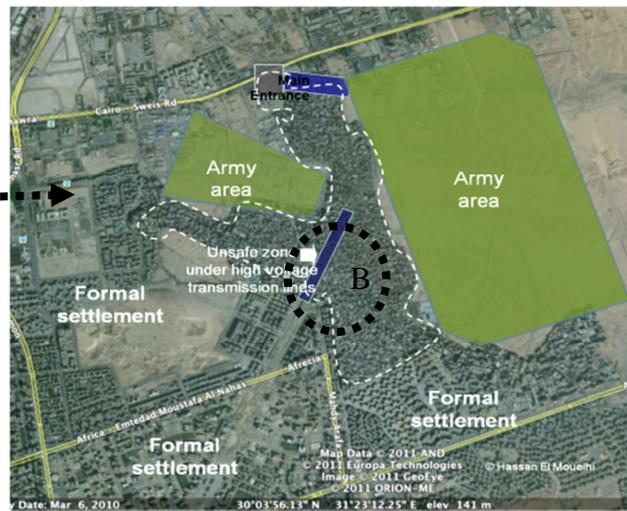
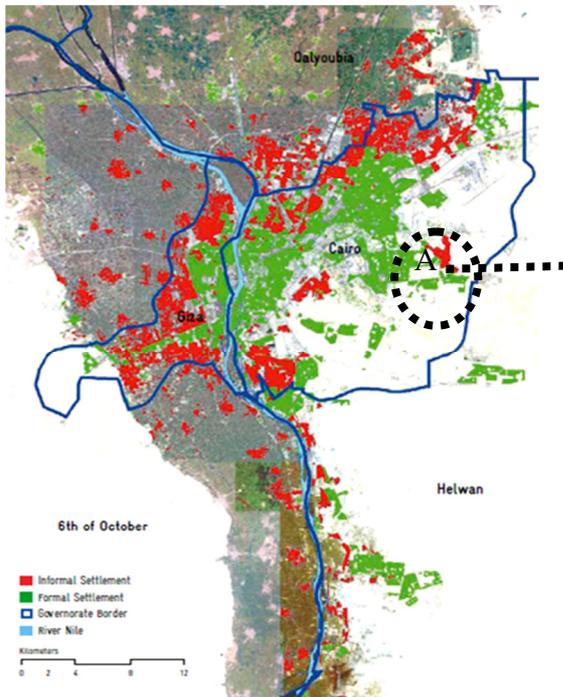
⁶Presidential Decree No. 305 for the year 2008 on the establishment of the ISDF under the direct authority of the Egyptian Prime Minister’s Cabinet after the collapse of the unsafe cliff of Al-Dwika in Cairo (isdf.gov.eg, 2008)

⁷ Egypt is using now 2013 constitution which was approved by direct voting system in December 2013, also the Presidential Elections are running during May 2014

These transitions collectively had an impact on public mistrust, at the same time led to gradual spread of Informal settlements as a self-developed solution. As a result, status of these settlements have been always swinging as sometimes they are indirectly blessed by the state, in which electricity and water meters are connected to them, while other times are seen as urban epidemic that they should be evacuated and displaced.

Informal Settlement in Cairo: Case of Ezzbet Al-Haggana

Background: As it has been demonstrated, Cairo has been much influenced by urbanization oriented policies, which have exponentially increased the city’s population times in the past 60 years. The migration of rural populations has in the past represented one of the major factors fuelling urban development; although the spread of Informal Settlements proves that this is no longer the case. Hence, Cairo has been located on the world map to have 4 out of 30 “mega-slums” in the world; in which one of them is Ezzbet Al-Haggana (Davis, 2006). Ezzbet Al-Haggana is home for more than one million inhabitants living on former state desert land in the north-east of Cairo Governorate. Ezzbet Al-Haggana which is named in street signs and maps as ‘Kilo 4.5’⁸, has started as a village for families of guard soldiers ‘Al-Haggana’ stationed nearby. Nowadays, it is a place for affordable Informal housing market (Al-Shehab NGO). There is an existing unsafe area (isdf.gov.eg, 2008) that is prone to the hazard of high voltage electrical power cables (See figure 3). As it will be discussed later, this vulnerable area would be the driving factor to variety of stakeholders.



A- Location of Ezzbet Al-Haggana in relative to Cairo Informal settlements (source of original map is PDP/ GTZ, (Sabry, 2009)
 B- Area prone to the hazard of high voltage electrical cables, which is estimated by the ISDF to have total number of 829 residential units (source of original basemap is google earth, while graphical representation and data source by ElMouelhi, 2014)

⁸ Called that name in the 60s; as it is located 4.5 km distance form last point from Heliopolis (Al-Shehab NGO)

Figure 3: Two layers of zooming in for locating unsafe area within Ezzbet Al-Haggana (Authors)

Methodology: This section represents the continuation of research work that has been a part of M.Sc. Team Project (PartNaR)⁹, which was a joint activity in 2012. The main focus was to investigate the ability of initiating a governance framework that engages the community, private sector and NGOs along with the relevant state representatives in Ezzbet Al-Haggana. Accordingly the below methodology in figure 4 was followed:

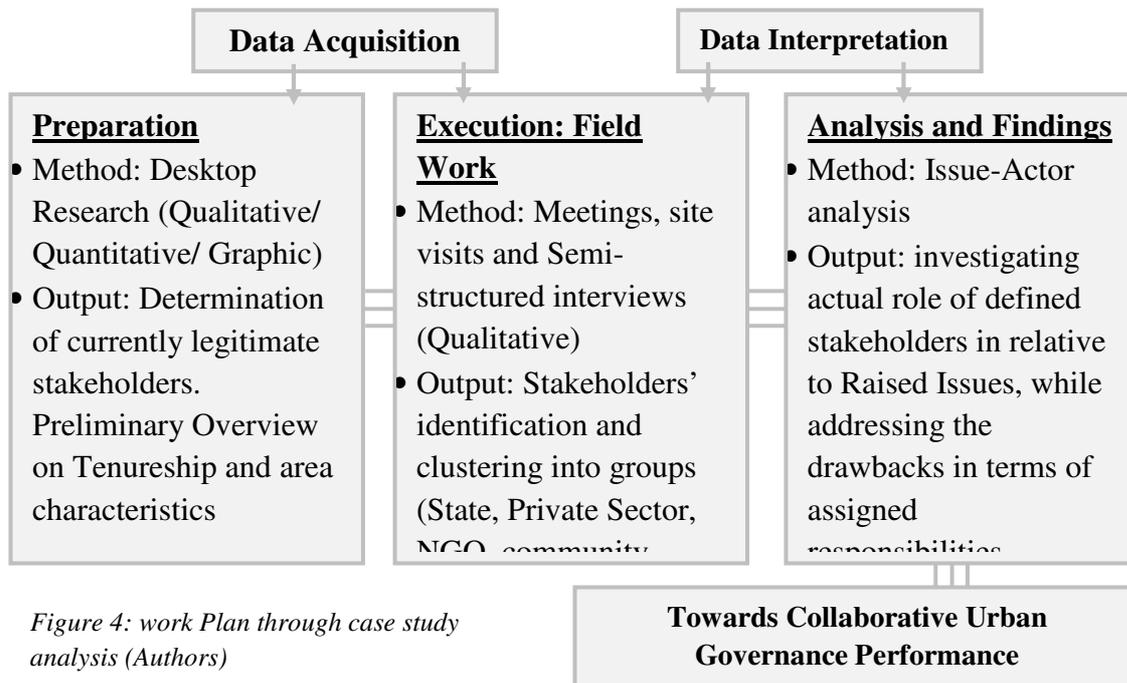


Figure 4: work Plan through case study analysis (Authors)

In this regard, role of three main stakeholder groups were investigated on ground:

- State represented in the Informal Settlements Development Facility (ISDF) who are mainly concerned with high voltage unsafe area
- Private Sector: Madinet Nasr for Housing & Development (MNHD) who are claiming to be the legitimate owners of the land
- Emarat Al-Ensan Foundation as an NGO who have facilitated interviews with community representatives (Men, Youth, Women, vulnerable inhabitants in the high voltage cable area, Local shop owners and Commuters)

Field Work Findings: certain findings were checked and briefly concluded below:

- Soci-Economic status: The inhabitants of Ezzbet Al-Haggana are mostly low-income families, where the area is recognized to have Car Mending very small workshops and some of the inhabitants work in service jobs in the surrounding area of Nasr City.
- Basic Urban Services: There is deficiency of services and infrastructure; for example, health care and education facilities, electricity, piped water, sanitation facilities, garbage collection, drainage system and paved roads.

⁹ Between Ain Shams University, Egypt and Institute of Tropics and Sub-Tropics, Cologne University of Applied Sciences, Germany

- **Tenure-ship:** The development of the area had no legal documents and totally relied on personal trust. The Inhabitants usually claim that their tenure status is formal through paying “Awayed’ which is property tax for electrical connections, and collect receipts for other items to gain as much paper legitimacy as possible.

Proposed Development Plans: were mainly triggered by MNHD and ISDF to transform the high voltage power line into underground cable, associated with Housing and Economic development including the residents as well

<p>A</p> <p>الجهة المعنية: محافظة القاهرة. محافظة القاهرة والقوات المسلحة. القاهرة والمجلس الأعلى للتخطيط العمراني. صندوق تطوير العشوائيات. محافظة القاهرة. محافظة القاهرة. محافظة القاهرة والقوات المسلحة. مركز معلومات شبكة المرافق محافظة القاهرة. افضة القاهرة وحي مدينة نصر شرق. محافظة القاهرة.</p>	<p>B</p> <p>Funding Agency: Madinet Nasr Housing and Development company Implementation Agencies: Madinet Nasr Housing and Development company and Cairo Governorate</p>
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Figure5: Stakeholders Identifying their Potential Partners for Implementation of proposed development based on Snap shot of official presentation to the Research team by both:

- A- MNHD, in which all named stakeholders are: Governorate authorities, ISDF, Military
- B- ISDF, in which all named stakeholders are: MNHD and Governorate authorities

Notes that could be directly concluded from figure 5 are:

- **There is no mentioning of any form of local inhabitants participation**
- Unclear terms of cooperation between ISDF as a state representative and MNHD as Private Sector Company; so as to protect the rights of the most vulnerable groups against investors’ interests
- Introduction of Governorate authorities and their detailed breakdown is provided through MNHD presentation
- Introduction of Military through MNHD presentation as Owner of Adjacent Land

Thus, formulating an adjusted urban governance model is required towards throughout: Identifying related Stakeholders, and correlating their roles to UN Urban Governance Model.

Identifying Stakeholders: Area-related Actors in light of the data collected and analyzed

State	Private Sector	Community	Others
<ul style="list-style-type: none"> •Governorate •ISDF 	<ul style="list-style-type: none"> •MNHD 	<ul style="list-style-type: none"> •NGOs •Inhabitants 	<ul style="list-style-type: none"> •Military •Sectoral Ministries

Figure 6: Stakeholders Identification relevant to the Urban Development of Ezzbet Al-Haggana (Authors)

It is important to mention that each of the mentioned actors in figure 6 can be broken down into smaller entities and represented on different scales. Also, this model is recommended to



be updated based on the specific development as there might be specific technical groups to be involved for example.

Reflections on UN Urban Governance Model: When trying to apply UN Urban Governance model within Ezzbet Al-Haggana the following table is concluded

	Direct Related Actors	Recommended Collaborations: Towards better Performance
Decentralization	Governorate Sectoral Ministries	On different tiers of governorate, decentralization should be promoted for facilitating the process of interventions and decision making process. However communication among these level should be essential as well as with sectoral ministries for Services Provision
Equity	Governorate ISDF NGOs	The fact of having an existing vulnerable community living in Ezzbet Al-Haggana increases the demand for equity measures. Hence, when proposing area development plans that should be responsibility of Public Sector and NGOs as advocacy agents of Urban Poor
Civic Engagement & citizenship	ISDF MNHD NGOs Inhabitants	In an attempt to support solutions that would resolve existing Conflicts regarding Tenureship and sense of ownership, and promoting the community Participation for that matter
Transparency & Accountability	Governorate ISDF MNHD	Public Private Partnerships always perceived to be corrupted, thus, certain measures and rules should be enforced to guarantee transparency and accountability
Efficiency	ISDF MNHD Governorate Sectoral Ministries	Feasible and Efficient plans and Capacity development are required to deal with Informal Settlements especially in the unsafe high voltage cable zone.
Security	Governorate ISDF Sectoral Ministries	Public Sector should be responsible for securing lives, resources and interests of Local community (inhabitants) and Investors(MNHD)
Sustainability	Governorate ISDF MNHD NGOs Inhabitants Sectoral Ministries Military	All actors should be this stage have identified roles that are not overlapping but more like to be harmonizing conflicts and integrating to reach a beneficial governance model that could guarantee a sustainable and responsive urban development

Table 2: relation of previously mentioned stakeholder for Ezzbet Al-Haggana in figure 6 to UN Urban Governance Model (Authors)

It is worth to mention that Table 2 illustrates only a sample of so many inter-linked and cross-cutting relationships among different actors related to Ezzbet Al Haggana. These links indicate the importance of each one of the mentioned actors and how much they are required to collaborate to achieve better and effective quality of life.



Conclusion

Informal Settlements are not only urban poor communities to be evacuated, displaced or traditionally upgraded then deteriorate after quite some years. Hence, Informal Settlements are more like to be an interactive and sensitive part of the city fabric that should be effectively integrated. Subsequently, this research attempted to introduce UN Good Urban Governance Model as a method to identify the required stakeholders to be involved for achieving the corresponding desired values within this model. This has been demonstrated within the case of Ezzbet Al-Haggana in Cairo, in which it was concluded that:

- Indirect actors such as Sectoral Ministries should be involved through decentralized and efficient channels
- Participation of Informal Actors (Inhabitants, commuters, and contractors) should be considered in a sense of empowerment and engagement
- Desired outcomes should be listed transparently and divided in terms of Actors, Roles and Collaborations in order to effectively measure all of the exerted effort, time and money in an accountable manner

Eventually, the urban governance of informal settlements in metropolitan areas is not anymore something to avoid and assess as risk factor within any urban development. On the contrary as involving the right actors would shift this paradigm towards sustainable metropolitan cities

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Exploring ways to successful resident-driven infill development: Lessons learned from two cases in Helsinki area (Best Paper SB13 Oulu)

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Abstract: *Study aims at analysing factors promoting or hindering infill development project from residents' perspective. Altogether 10 theme interviews were carried out in two case commonholds located in Helsinki, Finland. Study findings suggest four important factors of infill development for residents: 1) project management, 2) third party information, 3) communication and 4) costs and benefits of infill development. The findings indicate that infill development is a complex phenomenon from residents' perspective involving rational calculation of benefits and costs but also emotional factors have impact.*

Infill development, resident, Finland

Introduction

The way of living is experiencing drastic changes as the population in urban areas and the trend demanding eco-efficiency are growing (e.g. [1]; [2]). Together these issues generate need to develop denser urban infrastructure. One approach to tackle the need is infill development.

Infill development has benefits. It increases population and generates more investments in the area contributing to maintaining the already existing services and offering new ones [3]; [4]. Moreover, infill development has positive influence on reducing poverty and providing security in the area [5], [3].

Also barriers to infill development exist and residents' opposition is among the most important ones [4]. Residents' opposition has various reasons; residents might be worried about losing their parking plots [6] or recreation areas [7] due to infill development. Also increased traffic caused by infill development has found to worry residents [8].

In Finland, much of the potential land for infill is located in areas built relatively loosely in 1960-70's. In these areas, a substantial proportion of land is owned by limited companies called commonholds, in which apartment ownership is organized through a limited liability company form. Defined shares allow the shareholder (resident-owner) to gain possession of a specified apartment or some other part of the building or site and gives right to participate in decision making related to the matters of commonhold such as infill development. Thus, in



Finnish context resident-owners of commonhold have significant role in infill development decision making.

The aim of the study is to analyse factors promoting or hindering infill development from residents' perspective. To reach the aim, resident interviews were conducted in two commonhold cases in Helsinki, Finland. The findings of the study are intended to contribute to management, planning and execution of future infill development projects.

Method, data collection and analytical approach

To identify the cases, Helsinki city officials were met and requested to describe infill development projects conducted during recent years. Based on discussions, two cases were selected. The idea behind the case selection was to identify extreme cases (straightforward case1 vs difficult case2). This choice was deemed to allow rich data.

In case1, infill development project took three years (2004–2007). The case includes six 3–6 floor buildings with 116 apartments built in between 1951–1953. The plot is owned by the commonhold. During the project separate plot was parcelled out for the infilled commonhold. The new commonhold includes 18 apartments in four floors.

Decision making in case2 took several years (2005–2012). The case includes two six floor buildings with 148 apartments built in 1959. Buildings are located on a plot owned by the commonhold. As in case1, plot was parcelled out and sold for the infilled commonhold. New five floor commonhold with 25 apartments was completed in 2013.

Semi-structured theme interview was selected as data collection method. Semi-structured theme interview is seen as suitable method especially when the studied topic involves issues the interviewee does not consider on daily basis (such as infill development) [9]. The themes developed for the interviews were stimulated by previous literature on infill development and several brainstorming sessions were held among researchers to revise themes. In the end, three themes were developed:

1. **General description of commonhold and general assembly meeting.** The reason for this theme was to gain background information about the cases and general assembly meetings. The choice was made as the final decisions on infill development are made in general assembly meeting.
2. **Description of the project.** The interviewees were asked to describe the project from start till end. The idea was to capture considerations of the project and activate interviewees' memory before going into more detail to the promoting and hindering factors.
3. **Promoting and hindering factors.** It was studied what interviewees considered important to form decision whether to support or oppose infill development thus to reveal the factors promoting and hindering infill development project.

Five interviews were carried out in both cases in 2012. Interviewees had been living in commonholds during the infill development project and were the owners of their apartments



with right to participate in decision making. The interviews lasted 45–90 min and were held in interviewees' homes or in public places. The interviews were tape-recorded and transcribed. Each interviewee received token worth of 30 euros for participation.

The data was analysed in following manner. The transcribed interviews were read several times. The reasoning for such approach was to develop provisional understanding, challenge it and further develop it through an on-going iterative process [10], [11]. In the end, abstract categories which manifest the promoting and hindering factors were developed.

Findings

Four main categories of promoting and hindering factors were established:

1. Project management;
2. Third party information;
 - a. professional information
 - b. layman information
3. Communication;
4. Costs and benefits of infill development project;
 - a. monetary and personal benefits/costs
 - b. functional benefits/costs
 - c. experiential benefits/costs
 - d. symbolic benefits/costs

Next paragraphs report the findings from the cases in more detail.

Case 1

Case1 was straightforward. The motive for the project was need for monetary resources to finance water pipe renovation. In the end, approximately one third of the expenses were covered by selling the plot to the infilled commonhold. This served as one reason for successful project. Further, residents considered the project understandable. The reason for this was *project management*.

Both chairman of the commonhold and the housing manager were active on the project. Interviewees described their work focused, determined and honest; issues brought up in general assembly meetings were well prepared and easy to understand. Two interviewees mentioned negative comments on management. Other considered that the managers had lack on both technical and financial knowledge while other was disappointed that the managers did not give residents opportunity to influence on design of the new building. However, project management was generally deemed successful.

“The then chairman of the board was very excited about it... He even planned some additional parts to the high buildings which would have been quite massive... And he planned the infill development and when the process moved on, nothing could have stopped it...” Male/case1



Third party involvement was minor. One interviewee mentioned that real estate developer participated some meetings and presented plans related to the new building, the easements allocated to commonhold's remaining property and shared functions of the new and old commonhold.

"I think some third parties were involved... but I wasn't in board at that time... I can't remember those who were involved, but I think there was some..." Male/Case1

Other type of third party information origin from *layman parties* such as friends, family and neighbours with which the interviewees had discussions about the project. The reason for these discussions was to interact with some unofficial party to reduce stress and monitor how the project is developing. However, those interviewees who mentioned such behaviour noted that these discussions were not to support decision making but to "release steam".

"Well, we wondered the construction... You know what they are doing here and what will they do there. How you can drive to the garage via that hill and then you should drive down there. And how our garbage bins used to be down there and now they try to fit those in that corner..." Male/Case1

The interviewees did not remember well what type of *communication* they received during the project. Some mentioned leaflets which were offered in bulletin boards and sketches of the new building on some website. In general, the interviewees did not consider that communication failed in any stage of the project and did not express need for more communication.

Monetary and personal *costs* were perceived by the interviewees. One interviewee stated that they lost money as the price of the sold plot was relatively low. Resident who opposed the project perceived stress and frustration because he thought that opposing residents were ran over and their concerns were ignored. This reflects other type of cost, personal sacrifices.

"Of course then the decision making was stressing when we waited the voting and the results... even though it began to look like the others will run over us anyway..." Male/Case1

Several *benefits* of the project were identified. Some were associated with the improved living surroundings and technical performance of the commonhold, i.e functional benefits. For instance, the water pipe renovation, partially funded by the project, contributed significantly to the technical functionality of the commonhold. Further, right of first refusal on the parking plots of the new building was given to residents. Other functional benefits emerged as well; some considered that services such as grocery stores and postal services in the area could be maintained due to the increased population.

"Of course, without the project there would be all renovations and their costs so if there wouldn't been the project, the pipe renovation would still be pressuring... So in that sense you can say it was worth of it." Male/Case1

The living surrounding improved as the new building was located on an unused and untidy area of the plot. Also townscape and the overall impression of living area improved due to the



new building. It was also considered important that the new building did not diminish green or other recreational areas such as playgrounds. All these refer to emotionally laden benefits.

“The area is now a bit more tidy what it was earlier when there was no building... It was quite a sharp cliff...”
Female/Case1

Case 2

Case2 had the same motive for infill development as case1; financial resources for water pipe renovation (the entire water pipe renovation was financed by infill development). Despite the financial benefits, the project was difficult leading to a division of residents into groups either favouring or opposing the project, several official complaints and even disturbance between residents. The following paragraphs tackle the reasons for difficulties.

Favouring residents perceived chairman's and housing manager's *project management* firm and determined. Contrary, strong criticism were given towards the project management by opposing residents who considered that the project was forced and decisions were made behind the commonhold administrative board's back leading to lack of trust in project management. In addition, the planning of the project was perceived insufficient with too little information to make decisions.

“The chairman has been deeply involved with this... I know her... And I gave her a right to represent me by proxy when I wasn't able to participate meetings... And she always informed me in very details what was decided and what happened... I never considered that I need something more...” Female/Case2

“We didn't get much information... And perhaps the worst thing was that the housing manager made some agreements about the road to the new building behind chairman's back... It decreased trust.” Female/Case2

Case2 included several *professional third parties*. These were: lawyer from the Finnish Real Estate Federation (chaired one meeting to control decision making), real estate agent who evaluated the financial impact of the project and served as advisor in negotiations between commonhold and other actors, lawyers who reviewed all contracts (reason was to avoid conflicts), Helsinki city architect who presented plans for the new building and real estate developer who informed residents about the construction work and its effect on residents' everyday life.

Some interviewees considered the professional third parties' involvement positive because it increased trustworthiness and assisted decision making. Times when decision making process complicated, third parties were found necessary to avoid complaints. Contrary, negative perceptions emerged. Especially Helsinki city activities were found problematic. This was related to traffic arrangements to the new building via commonholds' plot which did not please all. Residents were confused as they felt that Helsinki city did not have any reasonable justification for such decision and the officials did not want to listen residents' views. Another negative aspect was related to terminology third parties used which was not fully understood causing confusion and frustration.



“We had real estate agent who was some kind of an expert. And then we needed, mainly due to internal disputes, ask assistance from lawyers just to make opposition happy, so that all legal aspects have been noticed. And I think it was a good thing so that no one needed to question those anymore...” Male/Case2

Some interviewees perceived discussions with *layman third parties* positive. One interviewee discussed with relatives about stress the project causes; this had positive effect on his personal well-being. The discussions with other residents served different purposes. One interviewee discussed with her neighbours to understand what the professionals had presented in shareholder meeting. In other case, interviewee discussed with other residents about the opposing residents. This infused his belief into the project.

Some interviewees stated that *communication* was sufficient and assisted decision making. Information was delivered via bulletin boards and interaction with chairman. Contrary, some interviewees mentioned that content of communication did not match with reality (e.g. dates changed, disturbance caused by the construction work was underestimated). Some were confused as they did not know who is responsible for communication and who they should address if needed. Also the channel of communication did not please some interviewees. They perceived that relevant information should have been stored electronically which would have helped to keep track on the project and found relevant information easier.

“ How was the communication about the project?”

“Well, not very well. I didn’t always know what is going on.”

“Why so?”

“Well, they didn’t communicate at all... First they announced that it begins on that day... Well it didn’t.”

Female/Case2

Interviewees associated *costs* and *benefits* with project. Both interviewees who favoured and opposed the project perceived costs which were psychological in nature including stress and anxiety. The reasons varied. One interviewee considered that atmosphere turned negative due to constant quarrels. Other interviewee stressed the decision making outcome because she did not possess financial resources for water pipe renovation and she would have been forced to move away from apartment in which she had lived for a long time. Also difficulties to participate in decision making due to lack of competence caused stress.

“Well, yes it was somewhat stressful when small commonhold has two groups with such different views... Of course you can have your opinions, but when it went so far that you didn’t even say hello in the yard... That was stressful.” Female/Case2

Interviewees were concerned that the project will have negative effect on *functionality* of commonhold and the near area. The traffic arrangements via commonhold’s front yard concerned many interviewees as they considered that increased traffic causes danger to people. Daily routines were also feared to be disturbed as the new building cuts the most convenient path to local mall and current location of garbage bins will be changed. Finally,



one interviewee was not satisfied that the forest disappeared as she was concerned about the birds and their well-being.

“The problem which we will have... you should have own road to the new building, not via our yard. City was against it because it would have gone through park. And now the road goes via our front yard... I don't think it's a good thing, because we have already parking plots in the yard so the road increases traffic... It doesn't bother me that much because my windows aren't to the yard but those who have... It completely changes it... I think that caused quarrelling...” Female/Case2

Benefits of the project emerged. One major benefit was the financial support for water pipe renovation which improved commonhold's technical *functionality*. Further, number of people in the area was considered to grow which was expected to maintain current services and improve public transportation. Also benefits with *emotional* impetus were found; some interviewees considered that the area will be more comfortable and attractive when the untidy forest will disappear and the new building will change the area more urban. Also some *symbolic* benefits appeared. The status of the area was deemed to elevate as it will become more attractive due to the new building. Also relatively high apartment prices in the new building might attract wealthier people contributing to the area status.

“Because those will be owner-occupied apartments and so expensive... There isn't many people who can afford those... So it's definitely positive thing...” Male/Case2

Discussion

The study aimed at analysing factors which promote or hinder infill development project from residents' perspective. Analysis revealed four main factors which residents considered to either promote or hinder infill development: project management, third party information, communication and costs and benefits of infill development.

Based on findings, it seems that financial issues are not in a key role to enable successful project. In straightforward case1, the financial resources gained were minor compared to difficult case2. One explaining factor behind the differences between the two cases was project management. In case1, residents perceived only minor shortcomings in management. Case2 was different. Some interviewees considered the project management adequate while others were very sceptical on it. This led to the division of residents in two groups either favoring or opposing the project.

In Finnish system, the board of commonhold normally consists of resident-owners whose primary profession has nothing to do with housing, planning or construction. Further, infill development projects are not common in Finland. Still, Finnish society encourages commonholds towards infill development. This means that residents are put in a position in which they are responsible for preparing (commonhold board) and deciding (general assembly meeting) about the infill development. Such circumstances require a lot from project management. In case1, the leader of the project was found competent and dedicated to the cause while in case2 it became evident that some third party assistance would have been required throughout the project. As Finnish society is promoting infill development, the most



logical source of assistance would be the officials responsible for planning. However, in case2 the Helsinki city officials' actions mainly generated resistance between both favouring and opposing residents as residents considered themselves more professional on their own area than city officials. In the end, the project management was in a position in which the project went beyond residents' rational thinking and nature of the project turned into emotional one which manifested in quarrels and complaints without reasonable justification.

To conclude, it seems that the Finnish residents associate similar benefits and costs with infill development as suggested by literature [3], [4], [8]. Also other benefits such as symbolic ones and costs such as personal sacrifices were found. However, in the two studied cases these factors did not play the main role but other aspects were emphasised. Thus, to promote further infill development projects, the project management issue needs to be considered carefully. Still, infill development has potential in Finnish suburbs to promote more sustainable way of living. In addition, due to the Finnish system, it can provide significant financial resources for commonholds to be utilised e.g. in major renovations.

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McKinley Workshops: Sustainability Seen Through the Eyes of Children (Best Papers SB13 California)

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Abstract: *This paper describes a pilot project that consists of a series of children's workshops on environmental sustainability implemented at McKinley elementary public school in Santa Monica, California. In collaboration with educators from the school, a team of volunteers from HMC Architects developed a series of workshops about water, energy and waste specifically geared to elementary school students. The workshops were taught over three days in a two month period, and repeated for the school's 3rd, 4th and 5th grade students, totalling 240 students per day and more than 13 hours of instruction. In addition to the local students Venezuelan students virtually attended the workshop and interacted with workshop students. A post workshop review with teachers and students demonstrated the positive impacts of the workshops. If this pilot project was replicated physically and virtually it could help train the next generation of environmental stewards, positively impacting local communities and benefitting our planet.*

Keywords: *Sustainability workshops, sustainability education for children, energy, water, waste*

Introduction

Education is important at all levels and for all ages. In order to positively impact our planet it is important to empower our younger generation with the knowledge and the tools necessary to produce that impact. By bringing environmental issues to light in an interactive, fun and informative way, we were able to inspire children to become the champions for the environment which they are all innately capable of being. Our sustainability workshop series strived to create a domino effect of knowledge sharing. Our goal for the workshops was for each child, student and participant to share what they learned during the workshop with their friends and families, thereby cultivating a culture of environmental leaders ready to take immediate action against the urgent issue of climate change.

1. Initial Planning

To ensure that the workshop fit the needs of the students and staff, we worked closely with the McKinley Elementary school teachers in Santa Monica to develop the content. The group decided to address three topics: water, energy and waste. We held these workshops in the winter quarter of 2012. Each workshop was 1.5 hours, and was repeated three times per day, for three days. Each of these sessions would include about 80 elementary students from the third, fourth and fifth grades. Each workshop consisted of an interactive presentation that employed a variety of teaching techniques including interactive group discussion, movement,

art, music and multi-media videos. Furthermore, the presentation included kid friendly and appealing characters for each subject, which were developed by a graphic artist. After the auditorium presentation, students would break into smaller groups to engage in a hands-on activity. Student volunteers from a local University, educators from McKinley elementary and volunteers from HMC Architects, a local architecture firm facilitated the workshops and hands on labs.

In addition to the students from California, students from Maracaibo, Venezuela participated in the workshops via Skype. Venezuelan students participated “virtually” and interacted with McKinley students at several moments during the lectures and hands on activities (Fig 1).



Fig. 1: McKinley students communicate with Venezuelan students during energy workshop.

2. Water Workshop

California is in the midst of a water crisis. With a growing population, water demand has been rising at an astonishing rate for the last 20 years; however water supply has been dwindling. The significance of this dilemma is the impact that it will have on future generations if action is not taken. The water workshop became a means to convey the importance of this challenge.

The beginning of the workshop presentation focused on the ephemeral and practical uses and benefits of water. The presentation focused upon the notion that water provides us with fun, refreshment, and even electricity; however most importantly, water was defined as precious and scarce. Students were surprised to find that only 3% of the Earth’s water is actually drinkable. However students were even more mystified by the fact that only 1% of that 3% was actually accessible water, while the remaining 99% was frozen in ice caps or glaciers. Several interactive and age appropriate strategies were implemented to emphasize the issues. For example, all students were asked to stand and then three students were asked to remain standing while the rest of the students were asked to take a seat. We explained that these three students represented all the water on Earth that is drinkable. Lastly, two students were asked to sit, with only one student left standing. We then explained that this one student represented all the drinkable water on Earth that we had access to. Students were at first amused, but then surprised by the reality of our scarce water supply.

To help the students understand the science behind the water, the water cycle was introduced to the class in an interactive way (Fig 2). An animated diagram which illustrated the water cycle was provided. This was followed by an interactive “water cycle song.” Students at both McKinley and in Venezuela were asked to stand and sing together. Students were entertained with the notion that a science subject could become a song. However, the simplicity of the tune and the lyrics ingrained the steps of the water cycle into each student’s memory.

The impact of water was detailed in terms of where it comes from and where it goes. This provided students with a better understanding of how their actions can impact the environment as a whole. The route of water was detailed from the sky, to the earth, to treatment facilities, and back to the ocean.



Fig. 2: McKinley students sing and then build their own aquifers during the water workshop lab

As the majority of the water in the U.S. is supplied by underground sources, the concept of groundwater conservation and pollution prevention became the major focus. To demonstrate the concept of groundwater, students assembled their own small scale aquifers. Students were asked to layer materials and form a cross section of a typical aquifer. Using plastic cups, the students created a sloped hillside of earth using the following materials layered from bottom to top: sand, gravel, and clay. They then poured in clear water to represent untainted groundwater. Finally they were asked to drop “toxins”, represented by pomegranate and blueberry juice, onto the clay (Fig 2). The students observed as the pollutants slicked off of the clay, and trickled into the gravel and sand, and eventually made its way to the water. They also observed how the stain remained trapped deep within the sand. They then recorded their observations down on paper, drew diagrams of their aquifers, and listed ideas for how they could prevent water pollution. This exercise allowed the students to visually understand the immediate and long terms effects of pollutants on land and in our water. Students became aware that in order to have access to clean drinking water, they are charged with keeping their above ground environment clean and free of chemicals.

3. Energy Workshop

Energy consumption is one of the most important contributors to greenhouse gas emissions. A reduction of energy consumption is required to curb the effects of global warming. The

energy workshop aimed to teach the McKinley students alternative ways to conserve, use and even produce energy.

The energy workshop presentation focused on both the conceptual nature as well as the very tangible aspects of energy. Energy was described as being all around us, as something that every living thing needs in order to function. The more tangible aspects of energy were then presented, which included how energy is used to power our multiple electronic devices and cars. Students were then asked to draw what they thought energy “looked like” on a piece of paper and then discuss their ideas with a partner. The student drawings ranged from sketches of the sun shining down on plants, to diagrams of the sun providing solar power.

The effect of energy use on climate change was also discussed at length. To demystify the concept of CO₂, a short animation was shown which personified pounds of CO₂ as elephants falling from the sky and landing on the cities below. The students found the animation humorous and informational. They understood the notion that carbon emissions can be detrimental to our livelihood in the end.

This analogy of elephants as pounds of CO₂ was then extended to images that illustrated the quantity of emissions released into the atmosphere in various countries. The students were astonished to learn that the U.S. had the most pounds per capita of emissions, or “elephants”, when compared to all the other nations of the world.



Fig. 3: McKinley and Cal Poly Pomona University students work together to build and use solar cookers

To demonstrate the concepts of energy introduced during the first part of the energy workshop, a solar cooker lab was conducted. Solar cookers were an ideal method of showcasing how the sun could be used in an efficient way to provide a ‘free’ source of energy to conduct activities for everyday life. Architecture students from Cal Poly Pomona volunteered their time to show the McKinley students different models of solar cookers which they had built. The McKinley students broke into small groups and worked with the architecture students to create snacks such as s’mores, chocolate covered strawberries, quesadillas, and cheese and crackers (Fig 3). Students recorded their observations on paper. The architecture students then showed the elementary school students how to make their own solar cookers at home. The lab was highly interactive, fun and also a good role modelling experience for the architecture students.

4. Waste Workshop

The McKinley workshop series culminated in the third and final workshop which focused on waste. Waste was defined to the students as something that is used carelessly. To tie the three workshops together, waste was also defined as not simply being limited to ‘trash’, but which also applied to wastefulness of water and energy.

The students were introduced to a series of statistics about waste which proved to be illuminating. They were surprised to learn that The U.S. makes up only 5% of the population on the planet, yet consumes 30% of all the resources and produces 30% of all the waste, which equates to approximately 7 pounds of waste per person, per day. Furthermore, they learned that garbage production in the U.S. has doubled over the last 30 years.

Students also learned about current waste management practices such as landfills and incinerators. Diagrams were also provided which detailed how a landfill is used. Students discovered how waste housed within landfills can often seep into the surrounding environment, thereby polluting our soil, water, and even our air.

To combat the issue of waste, the presentation also focused on tactics that the students could employ at home or at school. These included the familiar mantra of: reduce, reuse, and recycle, but also included ‘new’ tactics such as sharing material possessions rather than buying new ones and composting food waste.



Fig. 4: Materials used for the waste busters lab and students interacting in the waste session

To demonstrate waste management tactics introduced during the presentation, a “waste busters” lab was conducted. The students worked in small teams. Each team received a bag of ‘trash’. Students were asked to sort the trash and eliminate or salvage as much as possible using the methods they learned about (Fig 4). Points were allotted for each method of waste management. The team with the most number of points would win the game. Students were then challenged to create new things out of the salvaged trash. Creations ranged from art work to a full ensemble of musical instruments. Students had fun and learned from these hands-on activities while learning about how to rethink the notion of waste.

5. Continuing Education

To broaden the reach and purpose of the McKinley workshops, our team decided to develop the series into an educational book, titled “Sustainability Seen through the Eyes of Children.”

Working with the graphic artist who helped to create the characters for the workshop, the three subjects are woven together through an illustrated storyline. The book is almost ready and is intended to be provided in both hardcopy and electronic copy for teachers, students and parents to use at home or at school. The appendix will include images of the McKinley students' work, as well as directions for each of the three subject labs.

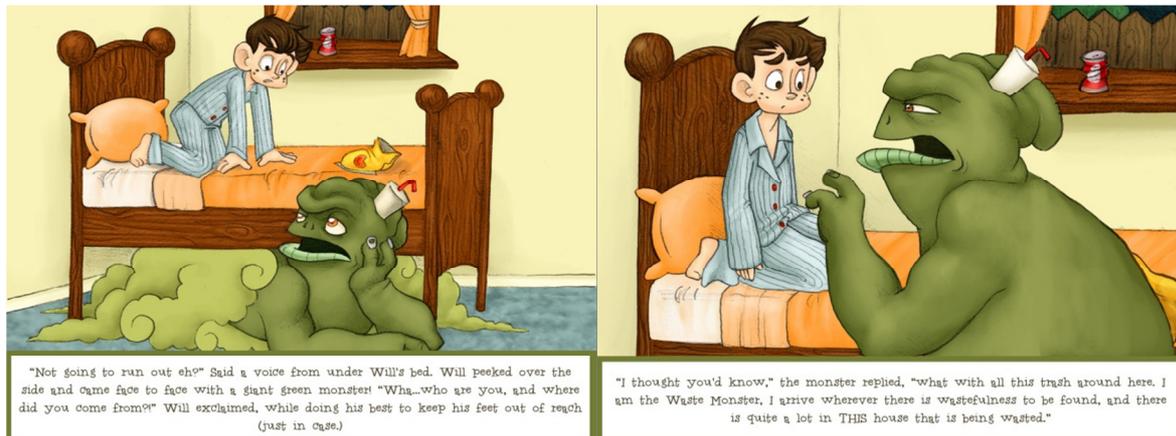


Fig 5: Illustrations by Sarah Banning from forthcoming book "Sustainability as Seen through the Eyes of Children".

In 2012, the McKinley Sustainability Workshop received the first USGBC (U.S. Green Building Council) Impact Award. The USGBC is currently working with our team to develop the workshop presentations into a template which would become available on the USGBC outreach website. In this way, these workshops will become an educational resource with an unlimited scope, reaching numerous environmental stewards and educators around the globe.

6. Measurable Outcomes

In order to assess the effectiveness of the program, a post-workshop interview was held with teachers, parents and McKinley workshop facilitators. Teachers were asked if they had noticed a marked difference in student perception or interests regarding environmentalism. The school's science teacher noted that weeks after the workshop, students were repeatedly recalling multiple facts they had learned during the workshop. A forum was held with 5th graders who had participated in the workshops while they were in 4th grade. The students shared that they continue to incorporate subject matter which they learned during the workshop into their everyday lives. For example students noted that they pick up litter from the ground to prevent pollution of the ocean, that they think twice about using a microwave rather than a solar cooker or that they are more conscious about not leaving the water running at home. This debriefing proved to our team that even a year later, the workshop was able to positively impact the social and environmental consciousness of 80 students. In this way the McKinley Sustainability Workshop was effective in disseminating pertinent information regarding environmental stewardship across the school-home front, and over the course of several months.

7. Next Steps



The McKinley Sustainability Workshop has the potential to serve as a tool in California's Education and Environment Initiative (EEI), which requires environmental subject matter to be a part of core curriculum in all state schools. Final EEI curriculum was approved by the California Board of Education as part of a 2005 state law. The curriculum will be implemented in 100 percent of school districts by 2014, reaching more than 6 million students in 1,000 school districts. Incorporation of the McKinley Sustainability Workshops into the EEI would be an effective way of reaching a broad age group of students in an interactive, learning conducive and memorable way. Since its first facilitation at Santa Monica- Malibu Unified School District, the McKinley Sustainability workshop has been implemented at several locations in southern California including the Diamond Bar Kindergarten, HMC's Kids Go Green Earth Day event, and as part of the activities of the exhibit "Technology and Environment: The Postwar House in Southern California" in the Kellogg Gallery at Cal Poly Pomona and part of the Getty series of exhibits Pacific Standard Time presents.

8. Conclusion

The McKinley Sustainability workshops provided students with a worldview perspective of environmental issues, thereby increasing their awareness and giving them practical suggestions on how they, as elementary school children, can build a better planet for all. The workshops also reminded our team of the hard but rewarding work that our elementary school teachers do every day. We felt accomplished to have transmitted some love for the environment and knowledge about environmental stewardship to 300 kids who were separated by more than 3000 miles; but sharing the same planet.

9. Acknowledgements

The work for these workshops was a collaborative effort of HMC volunteers and McKinley Elementary School staff, supported by the Designing Futures Foundation.

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Session 99:

Do particular examples allow generic results to be extrapolated?

Chairperson:

Gomes, Vanesa

Associate Professor. University of Campinas, Brazil



Energy Conservation in Existing Office Building: Case study Petrojet Company Head Office Buildings in Cairo, Egypt

Speakers:

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Abstract: *The energy performance in two administrative office buildings in Egypt is evaluated. One building is a traditional classic building while in the other building the designer consider energy efficiency and solar energy generated power contribution to the power required. The office buildings in this study has been designed with the compliance of the building regulation during their contraction time. The evaluation is done by ENERGY STAR. The main conclusions were that ENERGY STAR can be used to evaluate energy performance of office buildings in Egypt. Egyptian office buildings can compete the USA office buildings in applying energy efficiency strategies. In addition, energy efficient lighting and HVAC systems used in the new building save 19% and 64% of the energy used respectively and will save about 46% from the source energy used. In addition the GHG emissions / m² in the new building is half that of the existing one.*

Keywords: energy efficient building, ENERGY STAR, GHG reduction, energy performance

Introduction

Sustainability of the built environment needs to go in parallel with sustaining the natural environment. Therefore, building energy conservation measures received a fair amount of attention lately around the world as they offer a potential impact for significant energy consumption savings and environmental impact reduction. Industrial Modernization Program [1] reported that GHG emissions in Egypt are expected to grow up by 2030 contributing to ~0.9% of world emissions. It was added that the 5 main sectors of emissions are power production, building, cement industries, road transport and agriculture will grow up to ~ 77% of total emissions by 2030 while the building sector accounts for 12 % of the total emissions among the 5 main sectors. Hartungi et al. [2] cited that building more energy efficient structures may reduce carbon emissions by 60% or more, and will conserve conventional energy. Wang et al. [3] stated that a significant proportion of the energy used by building sector - about 40% of the global energy use - might be wasted due to various faults in building design, construction and particularly in operation stages. Liu et al. [4] stated that primary energy consumption in Egypt by residential and commercial buildings is expected to reach more than 35% by 2030. Hanna [5] cited that more than 60% of the total electricity consumption in Egypt is attributed to residential, commercial, and institutional buildings. He added that a significant increase in electricity demand is expected over the next few years with a growth rate of 8%. Artificial lighting is estimated to account for 36% of the electricity



used in the nonresidential sector and 35% of the electricity used for HVAC system. Sheta et al. [6] stated that climate affects the amount of energy that is used for heating, cooling and lighting. They added that experience from traditional architecture, which was fairly well adapted to the climate, is often lost or difficult to adapt to modern techniques and society. Lamborn et al. [7] stated that the operation stage can amount to the greatest proportional impact a building can have on the environment. Various governments and business organizations have recently tried to encourage the implementation of energy efficient strategies in the commercial building industry by funding the development of performance assessment tools. Lamborn et al. [7] stated that rating tools represent one of the latest initiatives to assess a building's performance during the design stages and informing designers of the impact of their decisions. This initiative provides benefits of reducing operations and maintenance costs from the reduction of energy consumption. It also facilitates reduce CO₂ emission from the building sector. There are various examples of rating tools. The Environmental and Energy Design (LEED) green building rating system and the ENERGY STAR are well known in USA. The requirements for the certification of LEED buildings are more complex than those for ENERGY STAR, and the certification process measures six distinct components of sustainability, one of which is energy performance. Energy Star certification is based only upon energy efficiency in building operation; this is clearly more important in property markets in which the price of energy is higher [8]. Currently, the primary standard for comparison is the ENERGY STAR Portfolio Manager (ESPM) [9]. ESPM looks at the whole building "in use" and evaluates a property based on its utility bills (after weather normalization). For the past two decades, the Egyptian government has worked feverishly to improve building energy efficiency and address GHG emissions. In that sense, developing energy efficiency building codes was a critical first step [10]. Egyptian Commercial Energy Code (ECEC) was released in 2009. However, there is little indication that there is a change in the overall design practices in Egypt towards improved energy efficiency. [12]. Throughout the survey, it was found that energy efficiency in buildings is a prime objective for energy policy on all levels due to the striking figure of environmental impact and energy consumption. Traditional design processes seem inappropriate for practices today due to the number of participants involved and the many issues to be considered. In addition, the absence of performance assessment tools in Egypt makes several questions remain unanswered on how energy efficient strategies can become a regular part of the design process. However, ENERGY STAR is a well-established rating tool. Therefore, the aim of this study is to evaluate the energy performance in two administrative office buildings in Cairo, Egypt using ENERGY STAR thus providing recommendations to enhance energy efficiency in existing office buildings for stakeholders.

Methodology and procedures

The energy performance in two administrative office buildings (Petrojet company head buildings) in Cairo, Egypt is evaluated. On one hand, the first is the existing head office which is a traditional classic building. On the other hand is the new head office that the designer consider energy efficiency and the solar energy generated power contribution to the

power required to this building. The office buildings in this case study were designed with the compliance of the building regulation during their contraction time. The evaluation is done by ESPM using the energy use intensities (EUI), i.e. kWh/m². Performance assessment results are obtained by comparing the performance indicators (e.g. EUI or CO₂ emission) against established benchmarks. [3]. ESPM requires a set of data based on a minimum of 50% occupancy, 12 consecutive months of metered utility bills, and basic building and space use characteristics, such as building size and location, operating hours, and number of occupants, to compute performance metrics. It normalizes for factors including climate, vacancy, and space use. ESPM does provide the means to prospectively analyze a building via a tool called ENERGY STAR Target Finder (ESTF). ESTF provides an estimate of what ESPM rating a building might obtain upon completion of 12 months of operation, if managed to achieve the estimated EUI [9].

Case study

Various data is collected for analysis from: (the projects concept design documents and reports and available bills - inspecting the buildings and its systems closely - energy efficiency and building codes in Egypt - trusted sites/organizations about ENERGY STAR program). The grounds for the selection and analyzing this two buildings is based on the fact that there are quite a few good practices that could be adopt to improve the building energy performance and energy conservation. The power of the systems and equipment used in the two office buildings was available. The energy used by the most energy consuming systems (HVAC, Lighting, and computers) was determined from the collected power data and illustrated in Table 1.

<i>Table 1 illustrates the collected data and the determined energy values (KWh/month) for the two buildings</i>		
	existing office building	New office building
Location	Cairo	New Cairo
Operating hours	From 7.5 a.m. to 3.5 p.m. (8 hours x 22 days) per month	
started operating	1962, Some modifications were made to the building 10 years ago.	Under construction
total gross floor area	10163 m ²	50900 m ²
Plan design	Open plan offices to allow more workspaces and more occupants. They are part of the energy conservation strategy as only one centralized area is being heated, or cooled, and lighted.	
total conditioned area	10163.016 m ²	50900 m ²
set point	25 °C	22 °C as indoor summer condition
Number of Occupants	826	1650
Number of computers	620	1240
Lighting	13685.76	55401.98
HVAC	22987.36	179778.72
Split Units	76736	0
Natural gas (m³/month)	0	44605.44
Equipment	21824	43648
Photovoltaic cells supplies	0	101250



Figure 1 shows the old head office building



Figure 2 shows the northern east corner of the new head office building design

Regarding the design strategy adopted in the new building has demonstrated the level of complexity involved in the design of an office building. The design is based on the aspiration for high quality architectural design, visual transparency from inside to outside, and a profile in keeping with the surrounding landscape providing a good view for the occupants that help enhance their performance. Regarding the lighting system, the daylight depth in the existing building decrease with increasing the width of the exterior walls as shown in Figure 1. In addition, 4x18 W fluorescent lighting fixtures are installed. On the other hand, in the new building, daylight is provided by allowing large openings in the North and East facades. However, Vertical and horizontal louvers are distributed on the building facades as shown in Figure 2 to prevent direct sunlight from entering the building. To complement the daylighting, the building energy conservation features are also increased by using a variety of energy efficient artificial lighting installations. It differs according to its location and the luminance level required. Compact fluorescent and led lamps are used. The compact fluorescent tube produce approximately the same light output as the larger diameter lamps of the same length and color temperature, but consume about 8% less energy [2]. Also reflectors have been carefully selected to make the artificial lighting to become more efficient. In some areas, the reduced overhead lighting is applied as appropriate, as it is anticipated that the task lighting will be used at some workspaces. Lighting control system is used (timers, dimmers and occupant sensors). Regarding HVAC system, in the existing building self-contained air cooled System is installed and closed spaces are served with separate split units. On the other hand, in the new building, roof gardens distributed on facades helps in filtering the air and decreasing its temperature through evaporative cooling. In addition, absorption chillers directly fired using natural gas is installed. Variable speed pumps are used to feed the chillers. Separated fan coils serve closed spaces. Two-way valves are used before each fan coil to control water flow. During winter, the chillers are totally turned off. Heat exchangers are used between supplied and exhausted air. The whole HVAC is connected to a monitoring and controlling system. Regarding the energy sources, grid electricity is the only source of energy used in the old building. On the other hand, in the new building natural gas is used. Approximately two third of the electricity used is supplied from the grid. The rest of the electricity needed is supposed to be provided from photovoltaic (PVs) modules. It was proposed by the project designer to install photovoltaic system on the building roof. **RET Screen 4** software was used to calculate the possible energy that can be provided by PVs considering the available roof area. **RET Screen 4** is an Excel-based clean energy project

analysis software tool that helps decision makers quickly and inexpensively determine the technical and financial viability of potential renewable energy, energy efficiency and cogeneration projects. The software provides a variety of PVs. *Sungen* poly-Si-SGM-230P with capacity 230 W/unit, efficiency 14.1 % and surface area of 1.63 m²/unit was selected. The system contained an inverter with capacity 500 KW and efficiency 95%. The roof area available for installing PVs can be used to install 3000 PV units producing 1215 MWh/year leaving 1936bMWh/year to be supplied from the grid.

Results and discussion

The energy use meter readings of the existing building are illustrated in Figure 3. This illustration represent the actual energy performance in the building. There are two meters applied. One is for the energy used by the HVAC system and split units. The other is for the energy used by lighting, computers and any other equipment using electricity. Total energy used during the period from January 2012 to April 2014 by HVAC and split units (3 GWh) is approximately double the total energy used (1.6 GW) during the same period by lighting and equipment. Therefore increasing efficiency of the HVAC system shows a great oppourtunity to save energy. The energy use distribution in the existing building is shown in Figure 4. It was found that the split units uses 68% of the total energy used by the existing building.

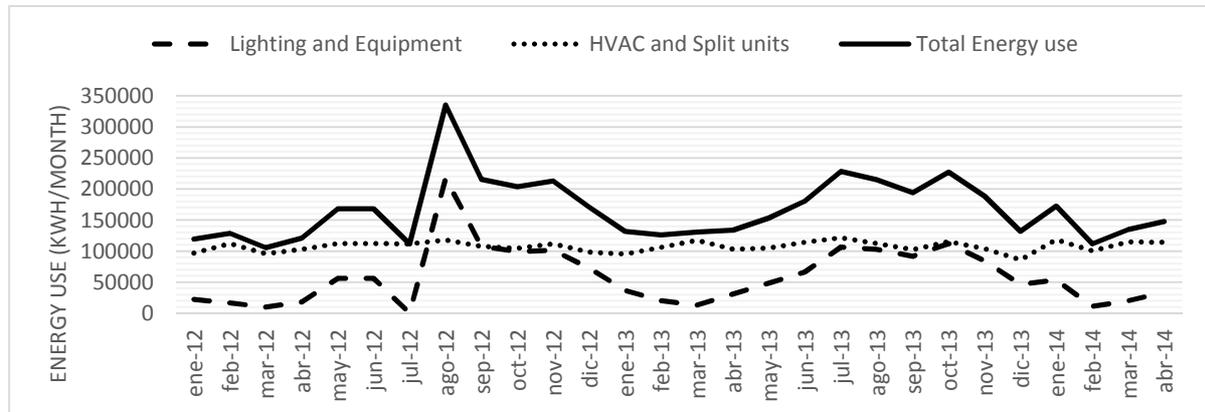


Figure 3 shows meter readings for energy use in the old head office building

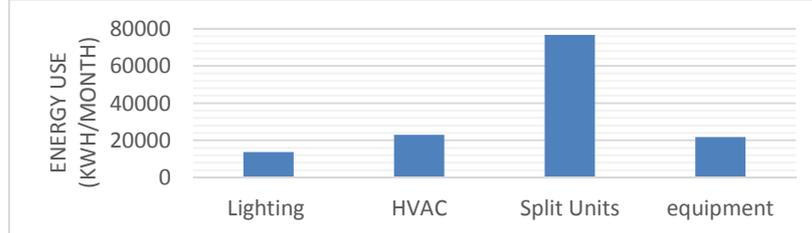


Figure 4 shows the monthly determined energy use distribution for the existing building

Considering lighting system, the monthly lighting and equipment energy use /m² (the determined and the obtained meter readings) for the two buildings is illustrated in figure 5. It was found that the energy use in the existing building for July 2012 is zero while the use for August 2012 is the most high value reaching 218 MWh/month which is nearly double the second most high value which is nearly equal to 112 MWh/month. This can be explained that the reading for both month July and August 2012 was taken at the end of August 2012. For about 11 months the meter reading is double the value of the determined energy use which

means that there is excess in the energy used. The annual energy used artificial lighting in the existing building is 16.2 KWh/m², while in the new building is 13.1 KWh/m². This means that the lighting system used in the new building is more energy efficient and saves 19% of the energy used in lighting. Considering HVAC system, the monthly HVAC system and the split units energy use /m² (the determined and the obtained meter readings) for the two buildings is illustrated in figure 6. For the existing building, it was found that the determined values are so close to meter readings which means that this system is working almost properly. Increasing HVAC system efficiency may need high cost measurements to be done. The annual energy used by HVAC system and split units in the existing building is 117.7 KWh/m², while in the new building is 42.4 KWh/m². This means that the absorption chillers used in the new building are more energy efficient and saves 64% of the energy used in conditioning.

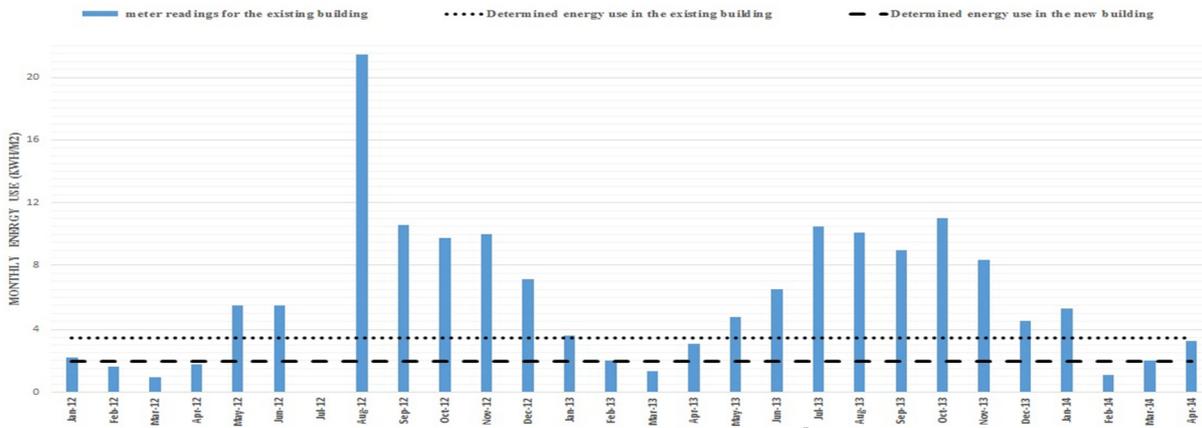


Figure 5 shows monthly lighting and equipment energy use per m² in the old head office building

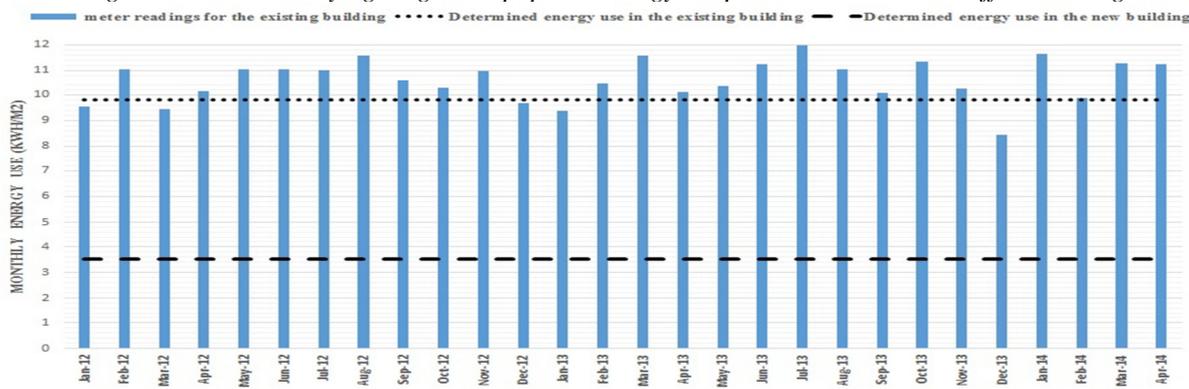


Figure 6 shows HVAC and split units energy use per m² in the old head office building

ESPM and ESTF evaluation results came as illustrated in Table 2 and Table 3. On one hand, the existing building estimated score as a design if the building was using the determined energy is 95. On the other hand, the score according to the actual energy use for 2013 is 75. The source and site EUI of the building is approximately double the targeted value. This means that by applying some energy efficient measures in this building, its score can increase and compete the USA office buildings in applying energy efficiency strategies. However, the new building estimated score as a design if the building was using the determined energy is 95 when targeting 100. The source and site EUI of the building is approximately exceed the targeted value by one third. This means that this building will be able to compete USA office buildings if it is constructed as it was designed using the same energy determined.



Table 2 presents ENERGY STAR results for the old head office building

Metric	Property Estimate at Design	Baseline	Current	Target*	Median
		(Nov 2012)	(Oct 2013)		Property*
<u>ENERGY STAR score (1-100)</u>	95	77	75	100	50
<u>Source EUI (GJ/m²)</u>	1.43	2.31	2.31	0.94	3.15
<u>Site EUI (GJ/m²)</u>	0.45	0.73	0.73	0.3	1.01
<u>Total GHG Emissions (Metric Tons CO₂e)</u>	710.5	1,150.10	1,150.70	467.7	1,573.10

Table 3 presents ENERGY STAR results for the New head office building

Metric	Property Estimate at Design	Design Target*	Median Property*
<u>ENERGY STAR score (1-100)</u>	95	100	50
<u>Source EUI (GJ/m²)</u>	1.25	0.81	2.7
<u>Site EUI (GJ/m²)</u>	0.73	0.47	1.57
<u>Total GHG Emissions (Metric Tons CO₂e)</u>	2,886.30	1,856.40	6,236.10

The source EUI in 2013 for the existing building is 2.31 GJ/m², while for the estimated design of the new building is 1.25 GJ/m². This means that the new building will save about 46% from the source EUI than the existing building. The estimated annual GHG emissions as evaluated by ENERGY STAR from the existing building is 0.11 tCO₂e / m² while for the new building is 0.056 tCO₂e / m². This reduction includes the net GHG reduction of 622 tCO₂/year provided when applying the PVs system proposal.

Conclusion

In this study, the energy performance of two administrative office buildings is evaluated using ENERGY STAR. After analyzing the collected data and applying the assessment tool, the main conclusions are:

1. Installing meter and sub-meter in building might provide potential benefit to energy conservation through monitoring. While this potential could be turned into real benefit only when awareness of the potential energy saving is turned into actions.
2. Split units use 68% of the total energy used while the total energy used during the period from January 2012 to April 2014 by HVAC and split units is approximately twice the that used by lighting and equipment. Therefore replacing the split units with energy efficient HVAC system and the increasing efficiency of the existing HVAC system shows a great opportunity to save energy.
3. The lighting and HVAC systems used in the new building are more energy efficient than that used in the existing one as lighting saves 19% and the HVAC saves 64% of the energy used.
4. ENERGY STAR rating tools (ESPM and ESTF) can be used to evaluate energy performance of office buildings in Egypt as the weather data for the Egyptian weather stations are defined on these tools. However, it is only allowed for American and Canadian facilities to apply for the certification from ENERGY STAR program until now.
5. Applying some energy efficient measures in the old head office building can increase its score and compete the USA office buildings in applying energy efficiency strategies.



Regarding the new head office building, it will be able to compete USA office buildings if it is constructed as it was designed using the same energy determined.

6. The results of ESPM and ESTF showed that the new building would save about 46% from the source EUI than the existing building. This proves that the systems installed in the new building are more energy efficient and also consumes less energy despite the fact that the new building is five times the gross floor area of the old one and include more occupants, more equipment and larger HVAC system. In addition the GHG emissions tCO₂ e/ m² in the new building is half that of the existing one making the environmental impact of one meter in the new building is half that of the existing one.

Acknowledgment

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Subjective and Objective Measurements of Thermal Comfort in an Austrian Active House: Occupant-reported Thermal Sensation and Measured Temperatures during a one-year Period

Speakers:

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Abstract: *The thermal comfort of the residential building Sunlighthouse in Austria is investigated with a particular focus on the summer situation and the role of solar shading and natural ventilation. The house has generous daylight conditions, and is designed to be CO₂ neutral with a good indoor environment. The thermal environment is evaluated according to the Active House specification (based on the adaptive method of EN 15251), and it is found that the house reach category 1 for the summer situation. It is found that ventilative cooling through window openings play a particularly important role in maintaining thermal comfort in all three houses and that both window openings and external solar shading is used frequently. The occupants have reported their thermal sensation daily during most of the one-year measurement period. The thermal sensation votes show good correlation with the thermal comfort category.*

Keywords: *Thermal comfort; ventilative cooling; residential buildings; natural ventilation; solar shading, Post Occupancy Evaluation*

Introduction

Five single-family houses in five European countries were built between 2009 and 2011 as a result of the Model Home 2020 project. Sunlighthouse (SLH) in Austria was completed in 2011. The house has been occupied by a test family in a one-year period, and measurements have been made during the period [1]. This paper focuses on the occupants evaluation of the thermal comfort.

The houses follow the Active House principles [2] which mean that a balanced priority of energy use, indoor environment and connection to the external environment must be made. The design has particularly focused on excellent indoor environment and a very low use of energy. There is a particular focus on good daylight conditions and fresh air from natural ventilation.

Measurements of IEQ include light, thermal conditions, indoor air quality, occupant presence and all occupant interactions with the building installations, including all operations of

windows and solar shading. Use of natural ventilation for summer comfort is based on ventilative cooling principles [3].

The presented results focus on thermal conditions, and the occupant's evaluation of the thermal environment. Some demonstration houses in Scandinavia have experienced problems with overheating, often due to insufficient solar shading and use of natural ventilation [4, 5]. Two British government reports similarly find that both new and refurbished low energy residential buildings have an increased risk of overheating [6, 7].

The house uses natural ventilation in the warm part of the year, and mechanical ventilation with heat recovery during cold periods. There is external automatic solar shading on all windows towards South.



Figure 3 Photo of Sunlighthouse by Adam Mørk

Each room is an individual zone in the control system, and each room is controlled individually. There are sensors for humidity, temperature, CO₂ and presence in each room.

The building occupants can override the automatic controls, including ventilation and solar shading at any time. Override buttons are installed in each room, and no restrictions have been given to the occupants. As house owners they have reported a motivation to minimise energy use on an overall

level, and to maximise IEQ on a day-to-day basis.

The recorded temperature data is evaluated according to the Active House specification [2], which is based on the adaptive approach of EN 15251 [8]. The results presented here are based on the measurements and analyses for the period in which test family have occupied the house, i.e. from March 1, 2012 to February 28, 2013.

The occupants responded to a questionnaire every day, where they reported their thermal sensation on a simplified 5-step version of the ISO 7730 [9] thermal sensation scale (as used in the present paper: hot, warm, neutral, cool, cold).

Results

Figure 4 shows thermal comfort categories. The house experiences temperatures in category 1 for 85% of the year or more for most main rooms. The temperatures outside category 1 are mainly in category 2 (low), i.e. between 20°C and 21°C. Temperatures above category 1 are very limited, and all main rooms achieve category 1 when temperatures below category 1 are disregarded.

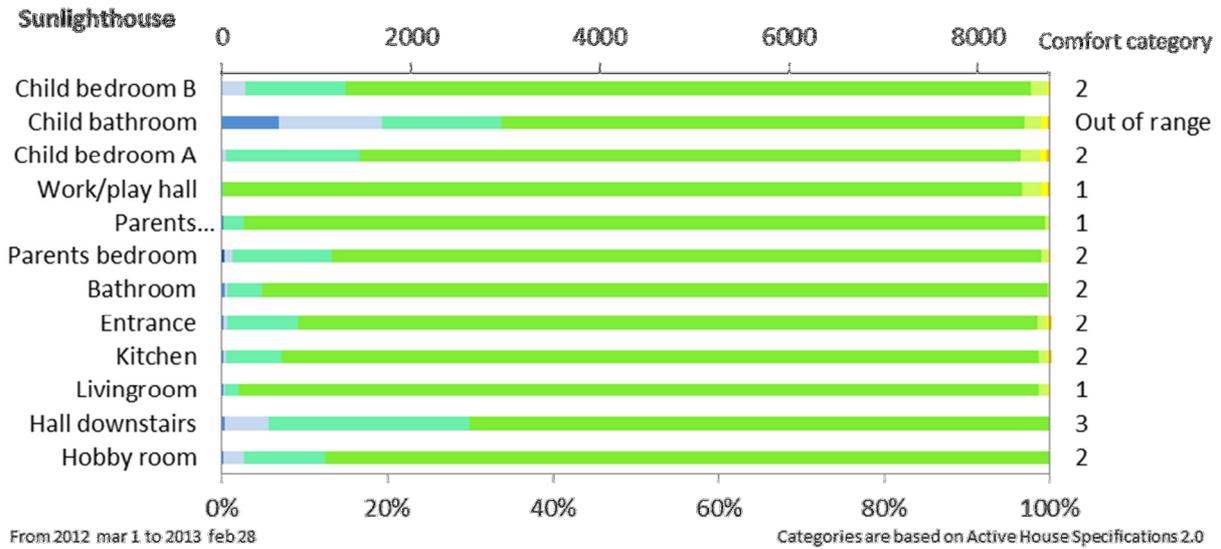


Figure 4. Thermal comfort for each of the rooms evaluated according to Active House specification (based on adaptive method of EN 15251). Criteria are differentiated between high and low temperatures.

The results in Figure 4 sum up the rooms’ performance as regards thermal summer comfort over the stretch of one year. The following analyses will focus in detail on the specific thermal performance of two exemplary rooms in each house, the master bedroom and the kitchen/dining room. The kitchen/dining room in each house has large glazed areas, which provides a risk of overheating, and therefore these rooms are investigated further. The Master bedroom is analysed as the thermal environment at bedtime has an influence on the sleep quality.

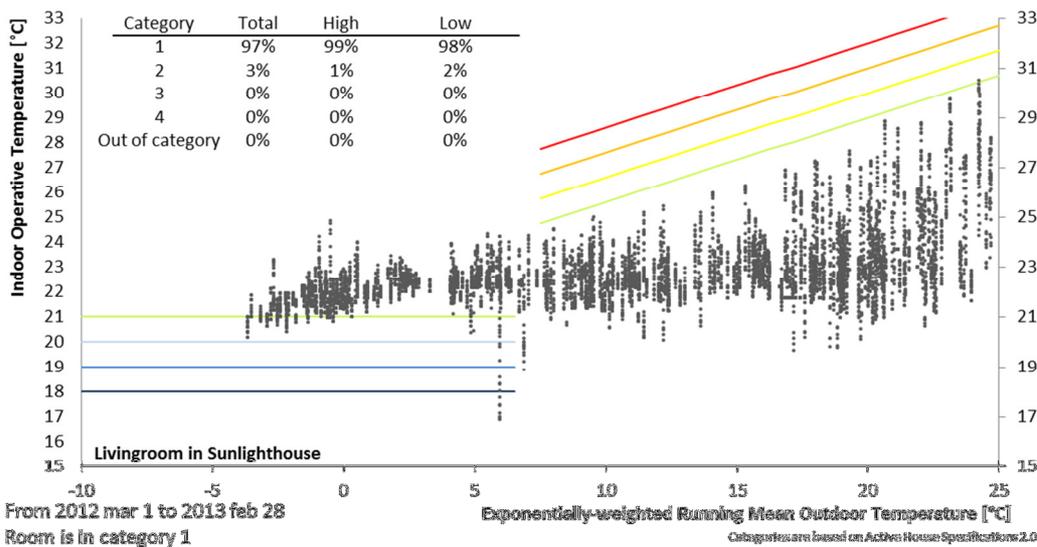


Figure 5. Indoor temperatures in the living room plotted against running mean temperature for each hour of the year including the Active House category limits. The percentage of time the room is in a specific category is shown. The column “High” disregards temperatures below category 1, and therefore represents “overheating”. The column “Low” disregards temperatures above category 1 and therefore represents “undercooling”.

Figure 5 shows the indoor temperature in the kitchen/dining room at each hour of the year plotted against the running mean outdoor temperature as defined in EN 15251 and used in Active House Specification.

Figure 5 clearly shows that the maximum temperatures increase with the outdoor running temperature, following the category 1 line. In the same period (running mean outdoor temperatures above 5°C), the minimum temperature in the living room does not increase with the outdoor temperature, but remains somewhat constant at approximately 20°C.

The variation over time-of-day and time-of-year is further investigated in Figure 6, which is using temporal maps (carpet plots), indicating each hour of the year according to its position in the day-of-year (horizontal axis) and time-of-day (vertical axis). Three to five episodes with temperatures below category 1 are seen, each lasting a day or two. In June, a few episodes with temperatures that reach category 2 are observed between 16:00 and 23:00. These episodes last for 2-3 days.

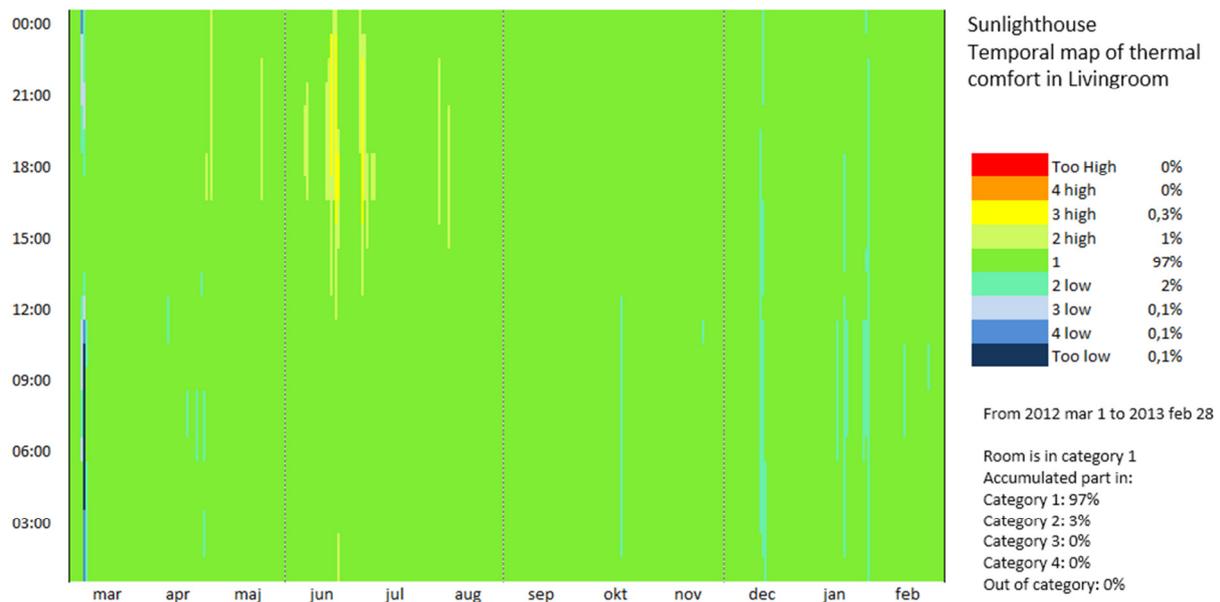


Figure 6. The comfort category of each hour of the year is plotted as a temporal map

To investigate the role of window openings in maintaining comfort, Figure 7 is used. A simplified comfort definition is imposed for the sake of the analysis, so that category 1 or 2 are combined, and also category 3 and 4. The figure shows if any windows were active during each hour.

Figure 7 shows that windows are used in the daytime during the transition period from March until May. From May until October windows are used also during the night for night cooling. The figure indicates that windows have played an important role in preventing summertime overheating.

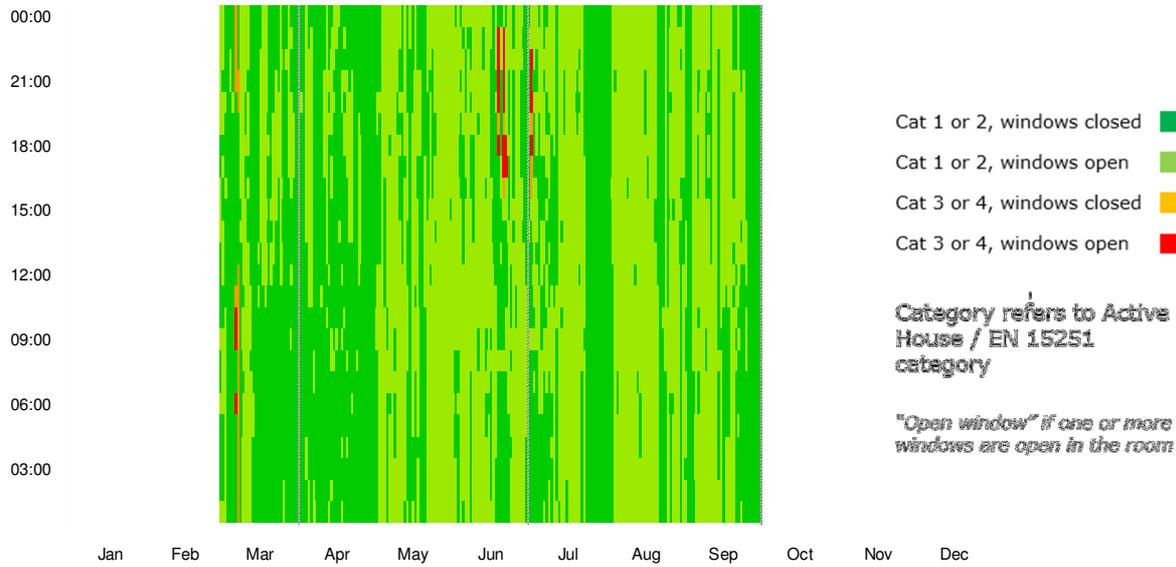


Figure 7. Temporal map of living room showing comfort or discomfort and if windows were open or closed (active or not active). Data from October and forward were not available at the time of the data analysis.

Figure 8 shows measured temperatures, thermal comfort category, and occupant-reported thermal sensation. During the very warm period at the end of June and beginning of July, the outdoor temperature reached 30°C. The peak indoor temperatures are 1 to 2°C lower during these warm periods, which means that the cooling potential of the outdoor air is used to a high degree. The indoor temperature does rise above category 1, but not higher than category 2. In this period the occupants rate their thermal sensation as “warm” or “hot”. The same correlation is seen in the beginning of August.

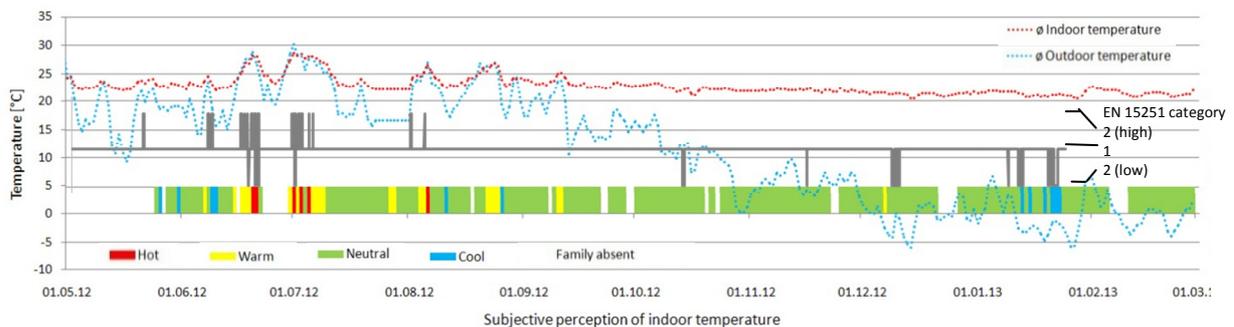


Figure 8 The dotted lines show measured indoor and outdoor temperatures in the living room. The grey line shows the thermal comfort category (1 or 2; can be high or low). The red, yellow, green, blue bars show the reported thermal sensation by the occupants.

During the last weeks of January 2013, the indoor temperature drops slightly below 20°C, which corresponds to category 2 (low). On these days the occupants reported their thermal sensation as cool.

In some episodes the occupants rate the thermal environment as warmer than the comfort category indicates (late July and late August). In other episodes the occupants rate the thermal environment as cooler than the comfort category (mid and late August).



In general there is good correspondance between the occupant's thermal sensation vote and the thermal comfort category based on measured data.

The accumulated days with a reporting of each of the thermal sensation scores are shown in Table 4. It is clear that the occupants report the majority (75%) of the days as neutral. 28 days are reported warmer or hot, and 12 days are cool.

Table 4 Number of days with a specific thermal sensation score during the period from May 1 2012 to February 26 2013.

Thermal sensation	Days	% of days
Hot	6	2 %
Warm	22	8 %
Neutral	211	75 %
Cool	12	4 %
Cold	0	0 %
Family absent	29	10 %

Conclusions

The houses are evaluated according to the Active House specification, which uses the same methodology and criteria as the adaptive approach for naturally ventilated buildings in EN 15251 with regards to thermal comfort.

Despite high daylight levels, the houses experience very little overheating, and less than reported for other low energy houses. All main rooms of the house achieve category 1 regarding overheating. Due to some hours with temperatures below 21°C during winter (by occupant preference), most main rooms achieve category 2.

Dynamic external solar shading and ventilative cooling by natural ventilation are key measures that have been used to achive the very satisfying thermal conditons during summer.

The occupants rated the thermal environment every day through almost a year on a 5-level thermal sensation scale. The thermal sensation votes are compared to the comfort category. There is good correspondance between thermal sensation votes and comfort category.

The results indicate that the adaptive approach of EN 15251 is reasonably accurate at predicting the actual thermal sensation of the occupants.

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Architectural integration of solar collectors on dwellings' roofs

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Abstract: *To incorporate solar energy in dwellings requires defining appropriate collectors according to housing typologies, constructive features and energy demand. This paper presents a research path towards determining highest potential active solar systems, considering architectural integration aspects, applied for dwellings in the city of Concepción, Chile. First, an urban map of roofs with overall solar radiation potential is developed to promote application of active collectors. Second, an analysis of roof geometries of detached housing is carried out. Typical roofs on the location were detected, and then potential local energy production is expressed through, accordingly to actual roofs geometry. Third, a study of an appropriate installation for a particular case is determined by an integrated design process due to the lack of architectural tools for early analysis. This work suggests the appropriate roof disposition for this context.*

Keywords, Building-integrated photovoltaic/thermal system, solar energy, housing

Introduction.

Lund (2010) discusses how cities should massively incorporate renewable energy in coming years, including active solar collectors technology in order to contribute to the energy grid with non-polluting sources and to reduce CO₂ emissions. This author mentions a necessary characterization of urban environments and its aptitude, considering different building distributions according to existing features, establishing different potentials and energy demands. A common scheme is a city centre with high occupancy rate, and presence of high-rise buildings accordingly to different uses in a dense urban center with administrative service, trade, or housing. On the other hand, on the periphery we find lower density buildings, mainly of residential use, and mostly occupied by single family homes, as well as some industrial buildings. This configuration characterizes Concepción city.

The middle-south region of Chile shows energy weakness, suffering international fluctuations prices depending totally on external energy market. Heating demand is an important issue because it depends mostly on the combustion of wood, which is usually wet and generates serious contaminations incidents (Universidad Católica de Temuco, 2013).

At this latitude of 36° 45' S, it is expected that roofing would have the highest potential for solar energy supply, but it is necessary to investigate on the best technology for maximum



solar energy capture for dwellings according to the urban form and how these technologies must be architecturally integrated. Photovoltaic electricity production at dwellings roofs could satisfy their electricity demand; but its low efficiency (4% to 17%) is a main barrier to cover thermal needs. The curves of solar supply and energy needs run in opposite way, which is a main barrier to cover a full building demand.

Urban map of solar potential

The method developed is based on general cartographic data, questionnaires and analysis of cases, due to the general lack of information and of three-dimensional information. Then, a territorial categorization of blocks based on surveys, socioeconomic levels, aerial photos, residential typologies and simulations are implemented on a Geographic Information System (GIS). This map identifies areas that express a differentiated distribution of energy consumption (electrical, water and heating) and solar gain; differentiating urban potential, which could constitute a basis for implementing a grid of renewable energy supply complementing different types.

Especially on the residential sector, appropriate strategies of solar gain and efficiency are identified to promote integrated building systems, such as panels on roofs of houses or building facades that allow assuming the entire electricity consumption as well as hot water and heating. The identification of these strategies is defined according to performance characteristics and local products, estimating characteristics of similar sectors, and making corrections of irradiation collected by climate records according to shading angles and topography. Differentiated sector maps are generated based on fuel sources, daily and seasonal fluctuations. Comparing the energy needs with the solar potential allows identifying areas of deficit and surplus, in different areas and periods, posing a catalog of effective systems of passive and active uptake, storage and local distribution, forming a dynamic GIS map of Concepción of energy consumption and solar potential to promote environmental actions.

Another product that has been developed within the project is the creation of an online map of solar potential for the municipality, which encourages the user to integrate solar collecting systems (photovoltaic or solar thermal) in their homes. The person can locate his/her property on the map, and identify the solar potential of the building, as well as savings that could be achieved in energy consumption in hot water, heating and electricity (*Image 1*).



Image 1: Solar potential and schematic tool's overview proposed to determine a stand-alone building potential. (Author)

Geometric characteristics and common indicators of dwellings' roofs for solar collection at real-estate house typology.

IEA (2009) describes cities or urban areas which incorporate massively active solar systems and relevant conditions; Hachem (2012) exposes a methodology to estimate solar potential at dwellings' roofs and neighborhoods, however, this is not an alternative to size potential of those existing buildings; alternatives have been published to determine roofs of buildings in cities by estimating the overall energy mapping systems GIR or LIDAR overflights aerial shots (Lucak & Salik, 2013); but there are no methodological proposals to size possible energy capture through its façade or tilted roof wing with better fitness by size, tilt or azimuth. This second method approaches to determine a theoretical wing-roof higher capacity; witch supposes to be faster investment return.

Satellite pictures of Google Earth 7.1.2.2041, the built-up areas of the city were detected at certain different times, according to dates and temporally sequenced scans. In Concepcion, the first frame corresponds to 2002, then to 2005, after that constantly had been updated annually, the last considered in this report corresponds to March 2013. At 2006 was adopted like starting-point, considering real-estate statistics log availability, plus building permits from municipality stats also (MINVU, 2013). With mentioned tool, recently real-estate dwellings built is determined; those who occupy more than 4000 m² of planar city are considered.

Roof's geometry traced with 17.0 Archicad BIM determines net available area; while occupancy, sloped sizing, roof surface against useful built internal area relationship were dimensioned. Useful roofs and façades are calculated: finding the Largest Wing Roof (LWR) by modelling, which proved to be relevant information because this item represents the best option to irradiation capture; a Second Largest Wing Roof (SLWR) is determined as an alternative when the best one is not suitable. Azimuth or orientation of LWR or SLWR from urban projects are obtained, in 84.84 % cases when LWR is not facing North or at least East or West, the SLWR wing-roof faces opposite, so on an adequate orientation; when not, they



are facing 90 ° respect to LWR, with good orientation. So accordingly to deviation, at certain point, the second option has more potential than a misguided LWR. These data allows finding improvements achievable with adequate urban and architectural design, considering solar collection and possible useful energy capture.

Topography, sun blockage or vegetation shading are beyond this approach, however, these house models have similar heights including different types, thus minimum direct irradiation blocking is expected incidentally at early morning and late afternoon, when solar intensity and energy production is minimum. Although, its important to include this aspect in city planning in the future (Cardenas & Uribe, 2012). IEA (2007) suggests expected losses by external conditions, which are further considered as general statistical losses.

Sizing Real-estate housing and its representativeness.

Through temporal satellite pictures comparison, an increase of 906,783.4 m² town occupancy is detected. Each neighborhood cluster identified at *Catastro Municipal Electrónico* catalog (Municipalidad de Concepción, 2014) was categorized by type and model, individually counted. Special attention was taken to identify over larger housing developments, corresponding to higher area occupancy and units available. 633,350.1 m² of city occupancy was in fact dated, corresponds to 69.8% of the total growth (*Figure 2*). 2139 houses present in 9 real estate developments from 22 were reviewed, including larger ones, between them: 485 homes from Valle Noble, 375 from Antilhue and 449 houses from Las Princesas. Main indicators are obtained from 3D roof models, projecting indexes to those not counted according to typological similarity model, number of units, density, etc.

A 289.47m² city occupancy per house has been measured. Growth between 2006 and 2013 were estimated over 3133 houses, corresponds to 90.6% of regular total permits issued according to *Observatorio Urbano de Chile* from 3458 permits emitted (MINVU , 2013); the remaining 9.4% corresponds to outsider real-estate neighbours houses or approved ones and not built . 2,139 dwellings compared to the entire housing stock 65,626 (CASEN, 2009), represents 3.3 %. Since 52,630 dwelling types were registered, a 4.1% fraction from overall was effectively dimensioned. It is not a representative sample of the general house typology, the models in real estate tipology differs from older house types, many built with unique design, governed by different municipal rules. The analyzed sample against 3133 units contabilized generated an error expected of 1.1% and a 95% confidence.

Housing quantity and quality and roof's geometry characterization.

There are nine clusters containing 2,139 individual houses, with 33 different models. Dwellings quantity by model varies from 1 to 339 units. House size oscillate between 57 m² to 170 m², an average surface of 93.71 m² was obtained, higher than national statistics (CCHC, 2011), but closer to city statistics (MINVU, 2013). Most models have two stories (98.7%); only two with 28 units handle three levels. Similar build typology between real-estate developments exists, all ground floors are masonry construction, second levels shows mainly lightwood or galvanized metal thin structure (similar to observed by Celis et al, 2012).

Planar roofs projection occupancy of 209,479.9 m² was dimensioned with corresponds to 23.0% of total city's area; the remaining space belong to gardens, roads, public space or terrace use. A tilted area obviously superior to horizontal projection corresponds to 129% respect to flat area. 3 to 12 facets per roof's house are accounted. Recurrence between 3 to 6 wing-roofs was counted (Figure 2). Larger houses usually show more faceted roofs. The average wing number considering all cases was between 5 and 6 wings (Fig.5).

Statistical analysis showed two custom slopes 26.71 ° or 40 °, in this situation are employed almost 1000 cases (47%). The average slope of all case of about 37.5 ° is found. Considering a 36.5 ° S latitude, the average roof's slope is pretty close to latitude, therefore suitable for photovoltaic technology (Hachem, 2012). Considering individual model analysis, slopes between 19.7 ° to 49.7 ° are observed. Usually every house model has a single tilt in all its wing-roofs, with few exceptions. 54.7% cases had superior slope between 40 ° and 49 °, higher than latitude, so appropriate condition for collecting useful thermal energy supposed. (Gajbert, 2008; IEA, 2003).

3D diagrams of each model were constructed to detect LWR and SLWR at each case (Image 2). It allows an area to display solar collectors measurement. According to LWR / built-area relationship and solar capture potential, most cases are between a 0.25 and 0.45 per m² index. Extreme scenarios are 0.20 and 0.62. An average gauge of each case is 0.39. A relationship between LWR against available surface area is 0.13 m² per square meter of city occupied area is found like an average correspondence. A relationship between of wing roofs, useful house area and units were counted.

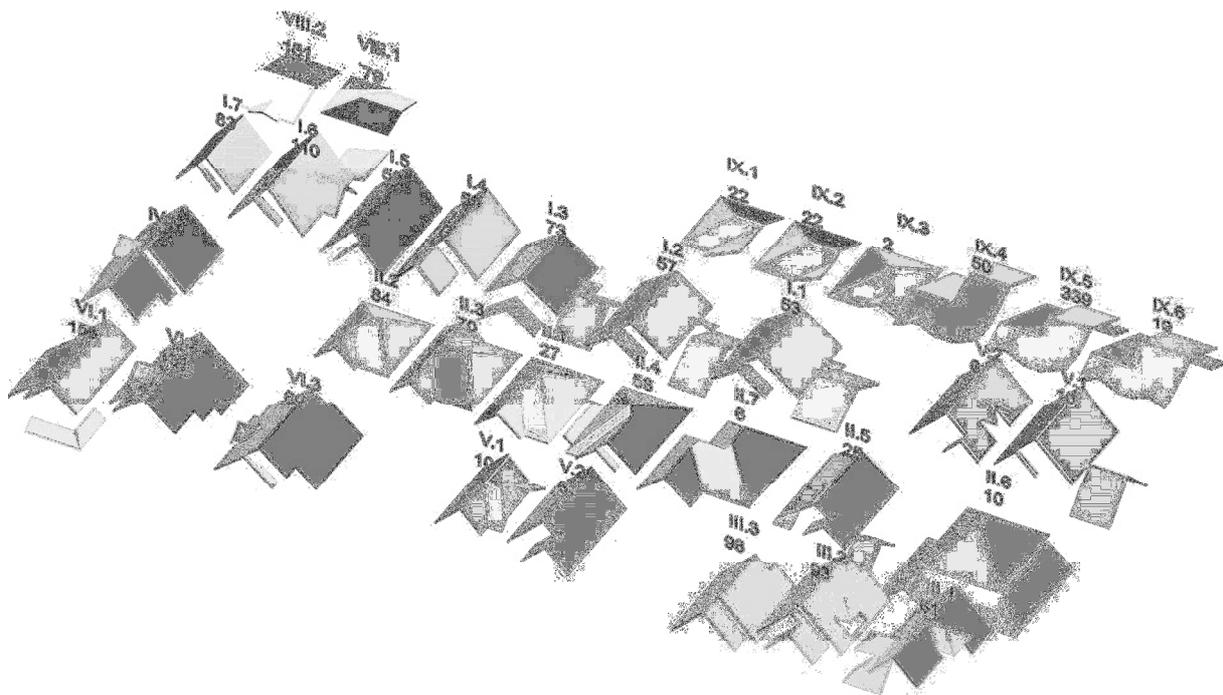


Image 2: 3D geometry roofs by model; in dark gray its Largest Wing Roof. (Author)

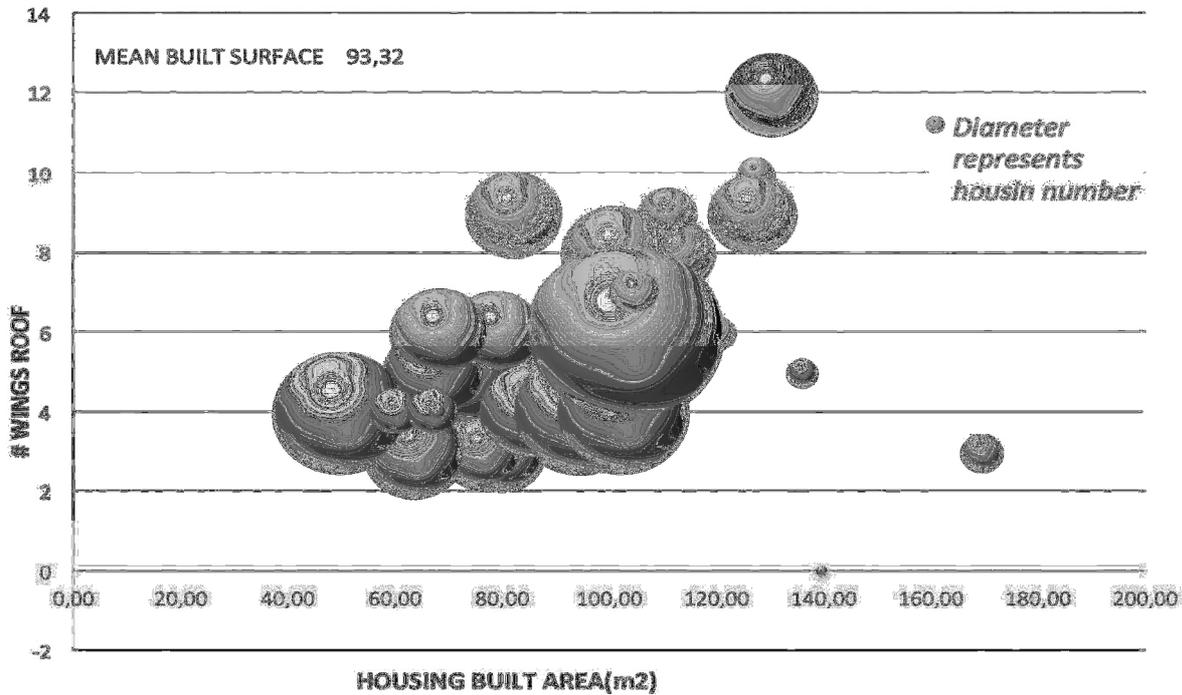


Image 3: Recurrence of wing roofs according to house model and household units. (Author)

Incident Solar Radiation on sloped roofs.

Two representative roof’s slope were obtained like an average index in accordance to main roof’s slope. About 1,163 units, corresponding to 54.4% of cases which average slope is 43.7 °; a second group of 976 houses, corresponding to 45.6% has a main roof’s slope of 26.8 °. A possible irradiation by m² was estimated in these inclinations according to orientation variance, until the breaking point when SLWR wing shows more potential than LWR wing roof. Net horizontal irradiation was considered accordingly to CDT (2007) published horizontal irradiation and formula expressed on 20365 Law (MINENERGÍA, 2010):

$$R_{Gm_inc-i} = R_{Gm_i} \times F_{d_i} \times [1 - (3,5/100000) \times O_{PS}] \times [1 - (PS / 100)] \quad [1]$$

Then: R_{Gm_inc-i} : Monthly solar radiation over sloped surface in kWh/m². R_{Gm_i} : Global solar radiation on horizontal surface on month i in kWh/m².

F_{d_i} : Modifying factor on incident radiation at an oblique surface for month i . This value is derived from *Annex II* of *Law 20365* (2010) (MINENERGÍA, 2010), according to the tilt and latitude.

O_{PS} : Solar Wing Roof Orientation.

* PS : Shadow losses [%]

* Shadows losses (PS) are not considered yet, this variable must be analyzed in each case. Subsequently statistically possible losses are determined according to IEA (2007).



When LWR shows a 113.0° relative deviation to true north, captured irradiation corresponds to SLWR rotated 90° , therefore it was considered a deviation when using SLWR a better option. The universe studied has been distributed evenly to different orientation to cardinal points according to LWR or SLWR caption. LWR quadrant suppose to contain houses with LWR solar caption within 226° to the north (113° deflection to east or west), this group corresponds to 1966.5 houses; then, the remaining SLWR group supposes facing within 134° North, corresponding to 1166 houses left.

To consider orientation of each dwelling, a statistical approach was done, observing each house real state urban development, houses are locate according to high land occupancy. So when orientation of each LWR house was counted, it could face indistinctly to different sides, and an evenly distribution was noticed, so an even distribution is determined. The dwellings universe were emplaced inner six possible orientations according to north deviation, three corresponding to LWR caption, divided in $18,83^\circ$ deviation the best oriented, then $56,50^\circ$ and $94,17^\circ$ deviations. Houses with SLWR capture were supposed to be $16,50^\circ$ and $50,25^\circ$ deviated

Total irradiation captures jointly according to different solar oscillations and wing collectors emplacement over LWR or SLWR, calculated at two average roof's slope and different orientations supposed with Expression [1] were estimated. Group with maximum production is obviously the one representing those less deviated from north with LWR, this group rotated 18.83° with sun capture from north and 43.7° roof's slope, they supposed to collect 21955.7 MWh per year; minor productive group is obviously one using SLWR with a highest deviation (50.25°) and 26.8° roof's slope, with an annual radiation captured estimated of 11,479.9 MWh. The best month for global sun energy capture is January with 19,236.0 MWh expected in all expected roofs; June has the lowest irradiation 7503.4 MWh.

Total annual irradiation measured of 164,906.2 MWh on these best wings, LWR or SLWR. It is possible to estimate useful energy production also, literature presents an average efficiency of $\eta = 16\%$ for installed photovoltaic grid-connected urban centers, and 25% losses expected from investors efficiency, distribution, shading, connecting factors, etc. (IEA, 2007). So useful energy production of 12% from total irradiation is possible (Pelland & Poissant, 2006; IEA, 2004), then a feasible total electricity production in 3133 houses of 19788.7 MWh annually was obtained, meaning 6317.2 kWh per household average production. This global data is constructed by considering an average 93,71 m² dwelling obtained in this research also, and then an output of 67.41 kWh of electricity per year per dwelling's useful m² was determined. This production represents 35,5% of total demand, heating included; considering just electricity, it may supply a 253,4% average; The total production area is 105,467.8 m² roof means an annual production of 187.62 kWh per m² (average of all LWR cases or SLWR capturing at different orientations).

Discussion.

This work has exposed an estimated capability for in-site energy supply through active solar systems applied to dwellings with sloped roofs, located in Concepción, Chile. A quickly overhaul shows global or individual houses from newly developed real state complexes in this context, its importance, representativeness and fast growth. Then, the current potential was determined considering a feasible use of solar energy through integrated solar collectors on



their wing roof with higher capacity considering dimension and orientation. It was determined a production and probability consistent with geometry deciphered, through municipality and state data plus a satellite map review and roof 3D reconstruction.

Then, current potential was determined by statistics and probability, which is consistent with the expected geometry, and calculated production according to energy demands statistically determined in previous studies. A possible supply of electricity in whole shall be established, making it possible to generate 19788.7 MWh per year. When compared to demand, this can supply in 35.5% of total energy demand, including thermal; then against just electricity on average supply of 252% was figured out.

This research has exposed an alternative to predetermine an overview of possible energy self-production through solar collectors to specific geometric roof environment placed. Although is necessary to explore precisely what kind of technology or collectors system must be used, in order to determine an optimal architectural integration with a proper technology.

Acknowledgment.

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An Intelligent Energy Management System For Sustainable Public Underground Spaces

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Abstract: Public transport operators suffer from the energy consumption of their underground stations. However, intelligent control of subsystems can significantly reduce their energy consumption without impacting the passenger comfort or safety or requiring expensive refurbishment of existing equipment. Within the EU project SEAM4US, a system for intelligent energy management of such public underground spaces has been developed, integrating components for the monitoring of the physical state of the station, passenger occupancy and energy consumption of all subsystems, as well as for the control of lights, fans and escalators. During its development, we have focused on building upon existing infrastructure that was not designed for energy efficiency while adding just as much additional technology as necessary. The system prototype has been deployed in the metro station Passeig de Gràcia–Line 3 in Barcelona, which we consider the first smart energy-aware metro station in the world.

Energy Efficiency, Building Automation, Building Management Systems, Model Predictive Control

Introduction

The largest part of the non-traction energy consumption of underground transportation systems incurs in metro stations, in particular through the lighting, ventilation and vertical transport systems. However, these are crucial for the safety and comfort of passengers. In this paper, we present a system for intelligent energy-aware control of these subsystems, significantly reducing their energy consumption while preserving passenger comfort and safety—the SEAM4US System. The system has been developed within the EU project SEAM4US¹ and builds upon existing infrastructure, adding new devices as required to enable energy-aware control, but avoiding expensive refurbishment of existing equipment where possible.

The SEAM4US System comprises sensors to monitor the physical state of the station, detects the passenger flow through CCTV image processing, and monitors the energy consumption through smart meters. Passenger density models and thermal models are integrated with

¹ <http://www.seam4us.eu>



sensors and control algorithms in a Model Predictive Control architecture that grants the optimal operation of the station plants under different occupancy and thermal conditions. In this architecture, environmental parameters of the models are fed with sensor data, allowing the system to predict the environmental state depending on the chosen control policy. The results of this prediction determine the actual control output, while the effects of this control are again monitored to contribute to the calibration and learning process of the models.

Control components have been developed to dynamically control the station lighting system, passenger transport, and ventilation. The result of this project is a complete prototypical solution for intelligent energy management of public underground spaces that integrates both existing and new infrastructure, which is currently evaluated in the metro station Passeig de Gràcia–Line 3 in Barcelona. In this paper, we describe the system, its software architecture and components.

System Overview

The SEAM4US control is based on a combination of different measurement and prediction inputs. Four kinds of data capturing categories can be distinguished. First, a sensor network measures environmental values such as temperature, air pressure or CO₂ concentration. Second, occupancy levels on the platform are detected by analyzing CCTV data. Third, arrivals of trains are considered by the SEAM4US System. Finally, smart meters measure the power consumption of the controlled devices.

Environmental and Occupancy Model components perform post-processing of the sensor data. As the SEAM4US control also considers future states of the station in addition to its current situation, these models implement prediction of the passenger occupancy and environmental state based on past measurements. Additionally, a local weather forecast service is employed.

All post-processed and predicted data influence how SEAM4US controls fans, lights and escalators based on a number of complex station models. The Controller component continuously evaluates the data and sends control commands to the respective actuator. Fan speed is adjusted proactively to optimize both air quality and energy consumption. The escalator energy consumption is reduced by setting its speed to a slightly lower level during most times and setting it to full speed only during peak times according to the passenger occupancy, thereby ensuring the required capacity for passenger transport. Dimmable LED lights have been deployed in the station, the brightness of which is controlled reactively according to current occupancy. While passenger safety requires more light when fewer people are present, luminosity can be reduced during peak times, however this level is obviously determined by legal and passenger comfort constraints.

The actuators communicate with the metro's SCADA system to assure the default control in emergency situations. Past and current measurements as well as the current control states can be supervised via a web-based user interface.

An overview of the system architecture is shown in Figure 1, including the core software running on a central server and the components dedicated to sensors and actuators. The LinkSmart Middleware [1] provides the communication infrastructure for networking, event-based publish/subscribe messaging and storage, as well as a supervision mechanism that raises alerts in case of malfunctioning of a component. It was enhanced to increase the performance of the event processing and storage system and to allow for better categorization of events, as well as to integrate the existing station hardware and the newly installed sensors and actuators, e.g., by adding Modbus/TCP support for the communication with PLCs and smart meters. In the following sections, we briefly describe the components in more detail.

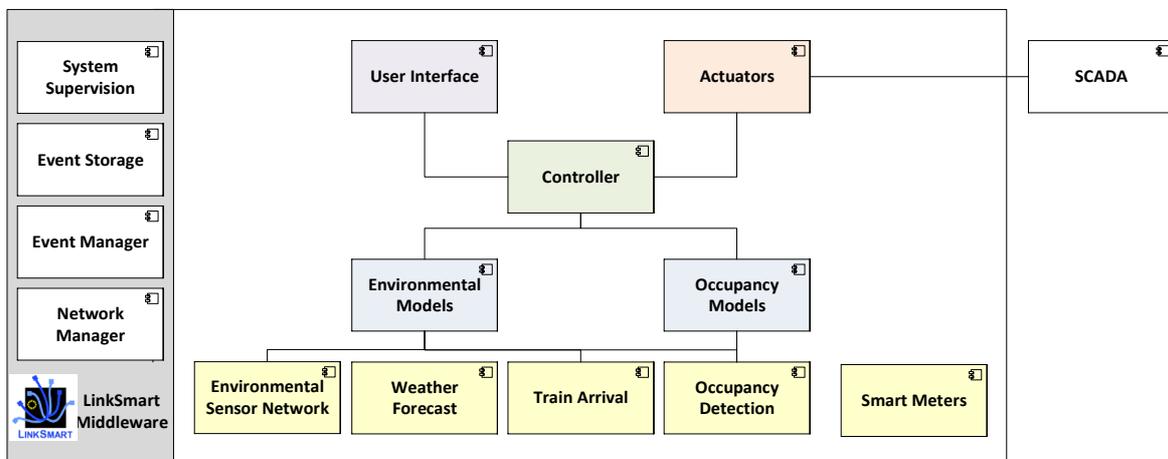


Figure 1. SEAM4US System Architecture, showing direct interfaces between components

Environmental Sensor Network

A large wireless sensor network has been developed and deployed in the station, providing the thermal model with the current thermal state of the underground space. It has been designed to minimize energy consumption and maintenance work, specifically optimizing the operation of wireless sensor nodes in order to reduce the battery replacement interval, and providing self-diagnostics and self-configuration capabilities in order to ensure correct operation without the need of human intervention. SEAM4US has also contributed new approaches for energy efficient sensor networks [2]. The positions of wireless sensor nodes and the frequency of sensor readings have been defined to allow the system to adapt to changes in energy consumption, user and environmental models.

Wireless sensor networks provide a prominent approach for environmental monitoring system in case communication or power infrastructures cannot be deployed or if the monitoring is temporary. Our deployment at the metro station satisfies these conditions, especially as the deployment must confer also a control system development which relies on a different set of requirements from the monitoring, e.g., by number of sensors. Typically, most of the sensor nodes are not in direct communication with the backend processing infrastructure, requiring the usage of a mesh network architecture, in which each device functions also as a relay for other devices in order to provide radio coverage of the whole monitored area.

In our scenario, the robustness of the communication was mainly affected by the dynamic radio environment caused by variable radio signal blockaging by the trains and people in narrow underground spaces. To mitigate this issue, a custom multihop routing protocol was designed, energy-efficiently selecting the most appropriate multihop path to fixed infrastructure in real-time. However, in practice some data loss in the network was caused through the restriction of the deployment in cases where sensor nodes had to be placed farther away to avoid vandalism, causing the node to fall out of the coverage area of the network from time to time.

Occupancy Detection

The Occupancy Detection component uses a CCTV-based crowd density estimation. It employs existing CCTV cameras and enhances them with a robust video processing algorithm that detects the number of people in the crowd. The algorithm, along with the software interfaces enabling communication with the backend systems, is running on a dedicated computer, which processes the data from a video recorder combining 20 CCTV video streams. The video streams coming from all cameras are combined into one single video stream by a video recorder, which creates a carousel video composed of sections of the individual videos appearing in a predefined order. For ethical and legal reasons, the video streams are processed on the fly without any local storage on the computer, thus protecting the privacy of passengers.

A calibration subcomponent sets up the regions of interest (ROI) and the perspective correction of the camera. An Optical Character Recognition (OCR) is performed to recognize the current camera of the video carousel, and the background detection is trained. This calibration is performed repeatedly throughout the execution of the image recognition. The actual crowd density estimation algorithm uses a combination of edge detection and background subtraction composed of several steps (for details see [3]).

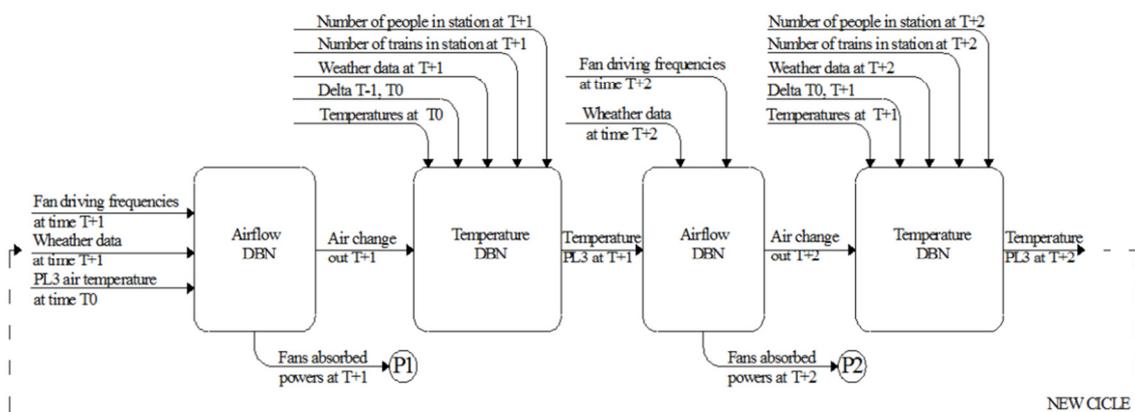


Figure 2. An example of prediction cycle of two time steps



Predictive Models

Two Bayesian Networks predict the thermal and the airflow dynamics. Combined in a unique prediction cycle (Figure 2), they provide forecasts of energy consumption and comfort inside the station in time steps of 10 minutes. The network's outdoor weather inputs are acquired from the commercial weather forecast service Weather Underground², which forecasts weather parameters at 20 meters from the ground level, accessible in JSON format. They are integrated with the temperature, CO₂ and PM₁₀ parameters measured at ground level by a weather station. The Occupancy Detection and User Model components provide the number of people in the station.

The initial Bayesian models have been defined by a model reduction process of a whole-building model of the overall station [4]. They are periodically trained with the data provided by the sensor network. The statistical nature of the predictor avoids any problems concerning the estimation of the initial state. The prediction accuracy achieved by the reduced models is good enough to get a reliable control of the station.

Prediction of passenger occupancy in a certain section at a certain time in the future is provided by the User Model. Prediction utilizes the output from the occupancy monitoring (CCTV data) as a sequence of values in a time series. As occupancy changes from time to time, it forms patterns (observation) which are comparable with other, known, occupancy patterns (history). Similar patterns in the subsequence suggest that most likely the next occupancy may be like the ones in the matched patterns. Alignment is known to work well particularly for patterns represented as a sequence of strings [5]. For the purpose of SEAM4US, patterns of the same location and equal time are compared in order predict the next occupancy.

Actuators

Actuator installations enable intelligent control of ventilation, escalator and lighting subsystems. Dedicated Beckhoff BK9050 Programmable Logic Controllers (PLC)³, deployed in parallel to the existing fan controllers, allow for stepless control of the fan frequency. Dedicated control logic ensures that operation of this safety-critical system is unimpeded and the existing SCADA system, accessible by operators in the station or the Operations Control Center (OCC), overrides SEAM4US control in emergency situations or in case of any failure of the SEAM4US system. The same PLC model has been used for escalator control, sending a signal to the escalator controller to switch the escalator to the slower speed of 0.4 m/s during most times. During peak times, or when SEAM4US Control is disabled, the full speed of 0.5 m/s is maintained. Additional presence sensors ensure the safety of passengers, allowing the escalator to stop when no passengers are using it and to start when a person is approaching. The LED lighting pilot installation is controllable through the Digital

² <http://www.wunderground.com/>

³ http://www.beckhoff.com/english.asp?bus_terminal/bk9000_bk9050.htm

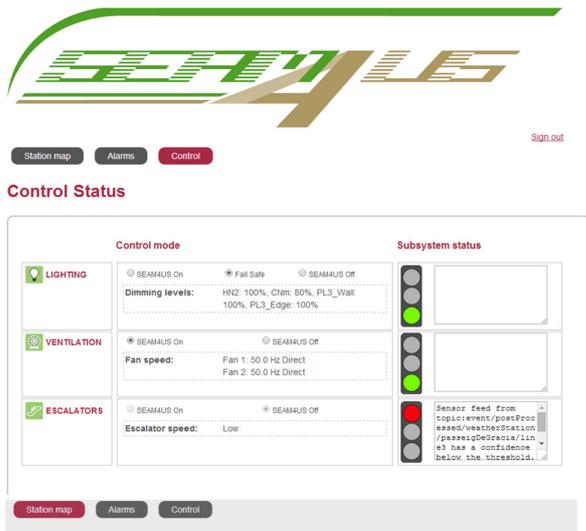
Addressable Lighting Interface (DALI⁴), and a DALI Gateway from Orama⁵ was installed to allow SEAM4US to dim the lights on a zone level through an IP-based interface.

Smart Meters

An extensive network of off-the-shelf smart meters has been installed to monitor the energy consumption during the operation of the system and feeding it back to the model. Submetering of all circuits in the station is achieved through Enistic BBSP-SM16D smart meters⁶, each allowing monitoring of 16 channels. Due to their highly dynamic energy consumption, dedicated Socomec Diris A10⁷ meters have been installed for escalators. The total energy consumption of the station is measured through a SACI MAR144 meter⁸, which can be readout by the SEAM4US System.

User Interface and System Supervision

The SEAM4US System includes a web-based user interface to provide project engineers with a status overview of the subsystems and allow them to set the control mode (see Figure 3). In a map of the station, all the deployed sensors can be explored and the recorded data visualized.



Besides this graphical user interface, operations and maintenance personnel can use the SCADA system and local hardware switches to switch between SEAM4US control and legacy control.

In order to be notified of a malfunctioning component, SEAM4US implements a supervision system. Each supervised component must implement an interface to access the status information, represented in three levels (*OK*, *WARN* or *FAIL*) and an optional (error)

⁴ <http://www.dali-ag.org/>

⁵ http://www.oramainc.com/digital_controls.php

⁶ <http://www.enistic.com/16-channel-semi-fiscal-distribution-board-smart-meter>

⁷ http://www.socomec.com/range-multi-function-meter_en.html?product=/dirisa10_en.html

⁸ <http://www.saci.es/en/component/virtuemart/140/29/network-analyzer/led/mar144-saci>



message. The SEAM4US supervisor continuously checks each supervised component. In case of a *WARN* or *FAIL* status, it sends e-mail alerts to a list of subscribers. Additionally, a daily summary is generated. This way, subscribers are aware of any malfunctions and of the correct functioning of the system as long as the daily summary is received.

Conclusions

In this paper, we presented the SEAM4US System. We described the overall approach of energy-aware control of subway stations, the SEAM4US System architecture and the individual components comprising the system. By means of comprehensive models of the subway station, integration of dedicated sensors and actuators with existing infrastructure, the its model predictive control architecture allows to increase the energy efficiency while maintaining passenger comfort and safety. Thanks to the SEAM4US pilot installations, the metro station Passeig de Gràcia–Line 3 has become the first smart energy-aware metro station in the world.

As a complimentary approach, but integrated within the overall framework, a strategy for involving passengers in the energy-saving effort has also been developed. A smartphone application rewards passengers for taking the stairs instead of the escalators. This allows the SEAM4US system to run the escalators in energy-saving mode for longer periods of time.

While the potential of smart energy-aware control of subway stations has only been shown in simulations so far, we are currently evaluating the pilot installations under real-life conditions. The results of this evaluation will be used to further improve the SEAM4US System, both to refine the models and control algorithms and to optimize the hardware and software deployment, thereby further increasing the efficacy and efficiency of our approach.

Acknowledgements

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Session 100:

Where should energy renovation reach up to? (III)

Chairperson:

Donath, Cristian

Eco Platform, Germany

Energy upgrading of residential buildings from the sixties, seventies and eighties with improved architectural quality

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Abstract: *This paper presents a study on how typical Norwegian wooden houses can be upgraded to a near zero energy level and at the same time preserve and improve key architectural qualities. Norwegian residential buildings are to large extent wooden houses, and 25 % of all residential buildings are detached houses built in the period from 1960 to 1990. These houses need upgrading. To make the good and smart decisions and spend the available resources on sustainable solutions is an opportunity for each house owner. This is also an opportunity for the government to use incentives to reach their goals for energy saving and CO2 reduction in the building sector.*

Key words: *Residential buildings, upgrading, energy efficiency, architecture*

Introduction

To make it possible to reach an ambitious level of sustainable renovation, we have looked for an approach that will result in houses with both high energy performance and other added value for the house owners like improved architectural appearance and improved indoor climate. From an architect's point of view it is always important to preserve typical qualities of the architecture from each time period. The aim is to balance and combine the new and the old, to preserve typical expressions and at the same time lift the appearance of the houses to a modern level. Three questions are therefore asked:

- What are the architectural qualities of residential houses from the 60-, 70- and 80 – ties?
- What is the potential for each epoch for upgrading to high standard modern houses?
- What are the smart and simple solutions that result in high energy performance and the desired added qualities?

Three design concepts have been developed, representing typical houses from each of the three epochs. The three concepts are optimised with respect to energy efficiency, daylight performance and improved architecture. Houses that need to be renovated usually need more comprehensive upgrading of some parts of the construction. The house may need a totally new roof, or the most comprehensive need may be to upgrade the walls with new windows, new cladding and added insulation, or the ground may need new drainage. The three design concepts are presented as a one step operation. The renovation will often be carried out in

several steps. This requires however a full plan as comprehensive as for the one step renovation to avoid energy lock-in situations.

The architectural qualities of the houses from the 60-, 70- and 80 –ties

During the sixties the detached houses were still quite small, as houses had typically been after the 2nd world war. Qualities from this period are efficient floor plans, simple harmonious forms, modest appearance and nice detailing, and built on site. During the seventies the houses became larger, and more houses were prefabricated. Efficiency was important in order to make more families able to buy a good home. During the eighties the variation in form, size and architectural influence increased. For this study, three typical Norwegian houses are chosen, one from each of the periods, the 60-ies, the 70-ies and the 80-ies. Concepts are developed where typical qualities are preserved and new qualities are added. An analysis of the qualities and the possibilities are carried out as shown in the table below.

	The 60-ies	The 70-ties	The 80-ties
In general	Relatively small and modest with good forms and volumes. Many of them are already upgraded and extended.	Typical houses from the seventies are important to investigate since a large number were built during this period.	Often quite large and decorated with bay windows, complex forms and several verandas and porches. Verandas and window bars often occupy much daylight.
Qualities	The simple and compact building volume is advantageous for energy upgrading. The plans are simple, the rooms are general and the houses have a fireplace.	Simple and compact building envelope. Often built on sloping sites, typical of the Norwegian landscape. Spacious with a ground floor that is partly a basement, but with windows in the front. Main rooms on first floor.	Houses from this period come in different sizes, mostly quite large and often with three floors.
Potential, possibilities and flexibilities	The flexibility is good with possibilities for building an extension. The load-bearing walls are central and give possibility for changing the roof or adding an extra floor. The interior walls can easily be removed and new and more contemporary floor plans and interior designs can be made.	The flexibility is good. The roof construction with roof trusses and no load-bearing walls give possibility for changing the floor plans easily within the existing building volume. Possibility for dividing horizontally into two apartments.	The houses are often large and could be divided vertically into two apartments.
Constraints	The sizes of the houses are small.	The roof construction with trusses makes it impossible to use the attic as living area or storage space.	The roof construction is not easily adaptable for new room plans.
Challenges	Substantial rebuilding is necessary to reach a contemporary design with larger kitchen and bath	If adding an extra floor, the whole roof must be removed and a new floor and roof must be built.	With bay windows and complex roof forms it is difficult to add external insulation.
Degree of upgrading			
Level 1	Energy upgrading and change of interior room plan.	Energy upgrading.	Energy upgrading and change of interior room plan.

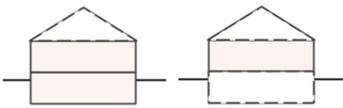
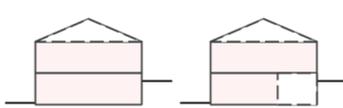
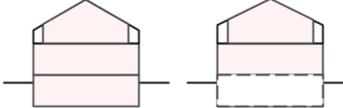
Level 2	Extension of the living area with added volume to the first floor or an added top floor.	Rebuilding the stairs by opening up with windows in the roof and walls for more daylight and better use of the ground floor.	Large houses can be divided horizontally into two parts
Level 3	Change the form of the roof to extend the height and the usability of the attic room.	Extreme change of the architecture.	Lift the roof and divide vertically into two parts.

Table 1: Architectural qualities, possibilities, constraints and challenges for typical Norwegian residential houses from 1960 to 1990.

The potential for upgrading to high standard modern houses

Norwegian residential buildings are to large extent wooden houses, and 25 % of all residential buildings are detached houses built in the period from 1960 to 1990. Many of these houses are now ready for main retrofitting and a large energy saving potential can be realized if the ambitions are high enough, up to 70% of energy consumption for heating and operation. There is also a potential for improvement of thermal comfort, indoor air quality, and the level of daylight.

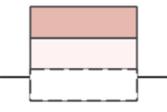
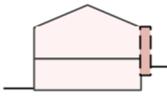
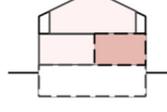
Typical construction and insulation levels are described in the table below. From 1960 it became normal to use light timber frame constructions and to insulate with 100 mm insulation, driven by the Norwegian state housing Bank, which gave better loaning conditions to those who could document a U-value of 0.40 W/m²K for walls, attics, or roofs. In the 1970s energy issues became more important and windows on the market improved (coatings and triple layer glazing), the houses built after 1980 usually therefor have a better insulated building envelope, ahead of the building code requirements of the time. The energy performance is calculated based on the assumption that each of the houses is heated with electricity and a wood burning stove, which is typical for houses without central heating. The calculations follow the Norwegian standards (NS-3031) and the Norwegian energy certificate for buildings. Relating to real consumption, air tightness and ventilation rates (currently based on natural ventilation), used in the calculations are based on estimates from these standards, and greatly affect energy performance.

Typology			
Key figures	Detached house, simple form. BRA basement: 76 m ² BRA main floor: 76 m ² 20 % windows / heated space Heated space (base case): 76 m ² .	Detached house in sloped terrain. Entrance and furnished ground floor. BRA ground floor: 85 m ² BRA main floor: 85 m ² 15 % windows / heated space Heated space (base case): 170 m ² .	Detached house with furnished loft. BRA basement: 62 m ² BRA main floor: 62 m ² BRA loft: 45 m ² 16 % windows / heated space Heated space (base case): 107 m ² .

Envelope	Timber frame construction, 98 mm insulation, 0.40 W/m ² K 100 mm to attic, 0.38 W/m ² K Fibersement insulation, 0.76 W/m ² K Dual layer windows, 2,7 W/m ² K Natural ventilation, 1,2 m ³ /h, Airtightness, 10 h ⁻¹ (50 Pa)	Timber frame construction, 98 mm insulation, 0.40 W/m ² K 150 mm to attic, 0.28 W/m ² K Insulated concrete wall, 0.66 W/m ² K Dual layer windows, 2,6 W/m ² K Natural ventilation, 1,2 m ³ /h Airtightness, 8 h ⁻¹ (50 Pa)	Timber frame construction, 148 mm insulation, 0.28 W/m ² K 150 mm rafted ceiling, 0.30 50 mm insulated Leca, 0.54 W/m ² K Dual layer EC windows, 2,4 W/m ² K Natural ventilation, 1,2 m ³ /h Airtightness, 8 h ⁻¹ (50 Pa)
Performance evaluation	Net energy demand: 300 kWh/m ² - Net heating demand: 241 kWh/m ²  Energy class F, Electricity + wood stove Delivered energy: 306 kWh/m ²	Net energy demand: 254 kWh/m ² - Net heating demand: 195 kWh/m ²  Energy class F, Electricity + wood stove Delivered energy: 259 kWh/m ²	Net energy demand: 214 kWh/m ² - Net heating demand: 151 kWh/m ²  Energy class E, Electricity + wood stove Delivered energy: 218 kWh/m ²

Table 2: Energy evaluation of Typical Norwegian residential houses from 1960 to 1990. It is assumed that the basement is unheated and not used for permanent living.

The concept designs were optimised according to current energy requirements for low energy building design. An ambitious level was defined, with up to 66 % heat loss reduction over the base case, (for the 60s house respectively).

Upgrade Concept			
	26 % windows+doors / heated space Heated space: 153 m ² .	28 % windows+doors / heated space Heated space: 171 m ² .	35 % windows+doors / heated space Heated space: 112 m ² .
Up-to-code (TEK-10)	+100 mm ext. walls, 0.21 W/m ² K 400 mm attic ins., 0.11 W/m ² K +50 mm basement ins., 0.20 W/m ² Triple layer windows, 1.0 W/m ² K Airtightness (50Pa), 2.50 h ⁻¹ Thermal bridge value: 0.04 W/Km ² Balanced ventilation, 80 % recovery Vent. rate, 1.2 m ³ /h. SFP 2 kW/m ³ /s.	+100 mm ext. walls, 0.21 W/m ² K +150 mm ext. concrete, 0.21 W/m ² K 400 mm attic insulation, 0.11 W/m ² K +50 mm basement ins., 0.20 W/m ² Triple layer windows, 1.0 W/m ² K Airtightness (50Pa), 2.50 h ⁻¹ Thermal bridge value: 0.04 W/Km ² Balanced ventilation, 80 % recovery Vent. rate, 1.2 m ³ /h. SFP 2 kW/m ³ /s.	+100 mm ext. walls, 0.21 W/m ² K 400 mm attic insulation, 0.11 W/m ² K +50 mm basement ins., 0.20 W/m ² Triple layer windows, 1.0 W/m ² K Airtightness (50Pa), 2.50 h ⁻¹ Thermal bridge value: 0.04 W/Km ² Balanced ventilation, 80 % recovery Vent. rate, 1.2 m ³ /h. SFP 2 kW/m ³ /s.
Performance evaluation	Net energy demand: 128.2 kWh/m ² - Net heating demand: 58.1 kWh/m ² Energy class C, Electricity + wood stove Delivered energy (If all EI.): 130 kWh/m ²	Net energy demand: 125 kWh/m ² - Net heating demand: 55 kWh/m ² Energy class C, Electricity + wood stove Delivered energy (If all EI.): 137 kWh/m ²	Net energy demand: 133 kWh/m ² - Net heating demand: 63 kWh/m ² Energy class C, Electricity + wood stove Delivered energy (If all EI.): 135 kWh/m ²
Ambitious	+200 mm ext. walls, 0.15 W/m ² K 400 mm attic insulation, 0.11 W/m ² K +50 mm basement ins., 0.20 W/m ² Triple layer windows, 1.0 W/m ² K Airtightness (50Pa), 1.0 h ⁻¹ Thermal. bridge value: 0.03 W/Km ² Balanced ventilation, 80 % recovery Vent. rate, 1.2 m ³ /h. SFP: 2 kW/m ³ /s	+200 mm ext. walls, 0.15 W/m ² K +150 mm ext. concrete, 0.18 W/m ² K 400 mm attic insulation, 0.11 W/m ² K +50 mm ins. on slab, 0.25 W/m ² Triple layer windows, 1.0 W/m ² K Airtightness (50Pa), 1.0 h ⁻¹ Thermal. bridge value: 0.03 W/Km ² Balanced ventilation, 80 % recovery Vent. rate, 1.2 m ³ /h. SFP: 2 kW/m ³ /s	+150 mm ext. walls, 0.15 W/m ² K 400 mm attic insulation, 0.11 W/m ² K +50 mm basement ins., 0.20 W/m ² Triple layer windows, 1.0 W/m ² K Airtightness (50Pa), 1.0 h ⁻¹ Thermal. bridge value: 0.03 W/Km ² Balanced ventilation, 80 % recovery Vent. rate, 1.2 m ³ /h. SFP: 2 kW/m ³ /s

Performance	Net energy demand: 113 kWh/m ² - Net heating demand: 43 kWh/m ² Energy class B, Electricity + wood stove. Delivered energy (If all EI.): 123 kWh/m ²	Net energy demand: 111 kWh/m ² - Net heating demand: 41 kWh/m ² Energy class B, Electricity + wood stove. Delivered energy (If all EI.): 122 kWh/m ²	Net energy demand: 118 kWh/m ² - Net heating demand: 48 kWh/m ² Energy class B, Electricity + wood stove. Delivered energy (If all EI.): 129 kWh/m ²
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Table 3: Energy evaluation of the rehabilitation concepts. Two target levels are shown, one ambitious level and one level where insulation of walls and requirement for air tightness are reduced to a level that barely satisfy the current building codes.

To reduce green house gas emissions further, the heating system (which is currently based on wood burning stoves and direct electric), necessarily needs to be replaced by a new low temperature water based heating system (i.e. floor heating for comfort, and centrally placed convectors). Because the heat loss is greatly reduced and the balanced ventilation system recovery unit provides base heating, fewer heat emitters are needed and greater flexibility can be obtained, since it is not longer necessary to place convectors under the windows. If a low temperature system is installed in combination with a biomass stove with a back boiler water circuit, the deep green heating label can be obtained. Alternatively, 6 m² solar thermal panels can be installed in combination with a geo-thermal heat pump and a low temperature system. Connecting dish washers, laundry machines and other hot-fill appliances will greatly improve the flexibility of a renewable energy supply, and relatively new innovations on the Norwegian market.

The smart and simple solutions

Three concept designs have been developed, representing typical houses from each of the three epochs. The three designs are optimised with respect to energy efficiency, daylight performance and improved architecture. Cost effective technical solutions will be investigated during the next step of this study.

Houses from the **sixties** are often small, and for this example an added floor is the solution to achieve larger living area. The kitchen and living room area is extended and located in one large room facing the garden. Larger windows give more visual contact to the garden and more daylight to the room. The bath room on the first floor is also extended in order to fulfil requirements for universal design.

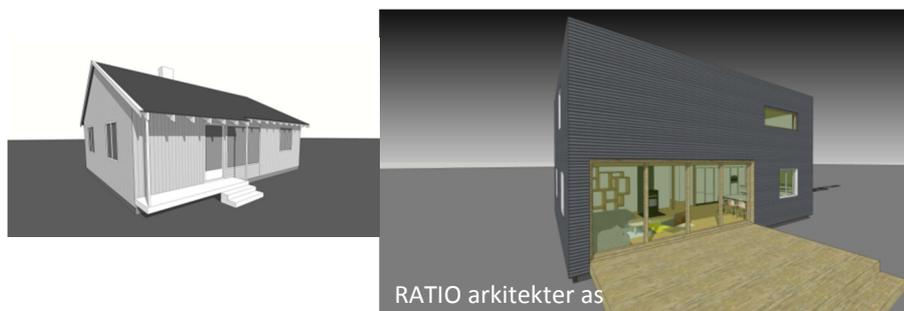


Image 1: Example solution for upgrading typical dwelling from the sixties developed by RATIO arkitekter as.

Houses from the **seventies** are quite large, and the possibility for renewing the facades during the upgrading process is important. Typical houses from this period are important since a large number were built. More efficient use of the ground floor and better communication between the different zones of the house has been the goal for this concept. The main design idea is open stairs through the building with windows on both sides and on the roof.



Image 2: Example solution for upgrading typical dwelling from the seventies developed by RATIO arkitekter as.

Houses from the **eighties** have large verandas that reduce incoming daylight. For this concept more daylight is achieved by adding windows to the roof and removing the veranda. The building envelope is simplified to make the external insulation process easy. A small extension gives extra space to the living area.

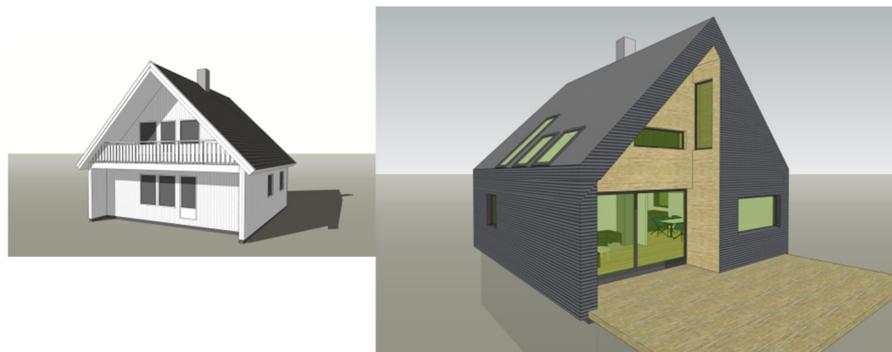


Image 3: Example solution for upgrading typical dwelling from the eighties developed by RATIO arkitekter as.

Barriers for ambitious upgrading

The costs for the concepts presented are not investigated yet. Costs are however an important barrier for ambitious upgrading. Some conclusions on cost for upgrading wooden buildings were however carried out for the residential buildings at Tollåsenga, Kristiansund during the REBO project (Kjølle 2013). Concepts were developed for energy efficient upgrading and rebuilding of the interior to meet the goals for universal design. The total costs were estimated to be almost as high as costs for totally new buildings. Upgrading of the building envelope to passivhouse standard counted for 40% of the total cost while full interior upgrading with new bath rooms and new kitchen counted for 50% and installation of lifts counted for 10%.



For Tollåsenga the cost became a barrier for energy renovation to a high level and less ambitious solutions were chosen. The limit for upgrading cost should be considerable lower than for new houses. However life cycle analysis may also be determinant for the decision whether houses should be upgraded or demolished.

Other barriers for upgrading to ambitious levels could be national regulations. Planning regulations will often limit the possibility to extend the building footprint or the roof form. Minimum distance from exterior wall to the plot boundary is constrained to four meters in Norway, and a layer of 20 cm extra insulation to the walls may require an exemption from this regulation.

Conclusions

This work shows some examples of concepts for upgrading residential detached houses to the level of modern energy efficient house. The goal has been to show possibilities to improve the architectural qualities, the energy performance, the daylight qualities and the thermal comfort.

To preserve architectural qualities that are typical for the period has also been a goal during this work. For these examples, the building envelope is totally new with extra insulation, new windows, new wood panelling and new roofing. Still important elements are recognisable, like window fenestrations and the simplicity of the building forms that are typical for the sixties and seventies. For the house from the eighties, the characteristic volume is the same even though the expression of the facades is simplified.

To reduce the costs is the most important barrier for upgrading to an ambitious energy level. To limit the costs the renovation work must be planed as efficient as possible and priorities must be taken. Development of systems for designing prefabricated elements that can be added on the building envelope is however a promising solution that might solve both technical and economical barriers. The next step for this study (called SEOPP¹) will be to try out one or two of the concepts on demonstration houses.

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Towards a resource and waste efficient built environment: Opportunities for renovation of transformable buildings

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Abstract: *While existing buildings are currently object of numerous sustainable renovation actions, long term effects are often forgotten. Large amounts of energy continue to be associated with renovated buildings due to usage of building materials over the remaining life cycle. Accordingly, a complementary closed-loop renovation approach must be introduced to include life cycle impacts linked with future changes and the end-of-life of buildings.*

Transformable building design stimulates resource and waste efficiency in the building sector: multiple reuse of buildings and components is anticipated during all future life cycle phases. By supporting and increasing transformability of existing buildings their structural system and new added building components become part of a circular economy.

In this paper the influence of physical building properties (plan configuration, structural system type, circulation, and assembly methods) on transformability of post-war building types is analysed by means of case studies. This analysis enables to formulate renovation concepts that can assist architects in improving not only the building transformability but also the sustainability of existing buildings in the long term.

Renovation, transformable building design, reuse, material and waste efficiency

Introduction: Re-design for change

Today, architects are facing up to the challenge of renovating our existing building stock in order to ensure sustainability for the future. In the context of the low carbon agenda of Europe the issue of excessive energy usage of outdated buildings - due to heating, cooling and lightning - is already being tackled, but an additional issue still remains: will the efforts of today be sufficient to deal with environmental problems regarding resource depletion and waste production in the future? A sustainable management of resources and demolition waste can only take place when architects also anticipate how buildings can keep on evolving during their life cycle and how they can eventually be disposed off in a proper way.

In order to support a material and waste efficient built environment buildings should be designed to facilitate alterations, i.e. as transformable buildings, that can easily change during the life cycle. Transformable buildings are not designed as an end stage, meaning that they anticipate future alterations, upgrade or transformation processes by facilitating dismantling, reuse and recycling of materials, hence, deal with the environmental burden of resource depletion and waste production [1]. Indeed, reuse of buildings and their components has proven to be far more energy efficient than demolition and re-construction, with large resulting environmental and economical life cycle benefits [2]. Transformable buildings incorporate reuse strategies at multiple design levels: building, component and material level. Building design must maximise the ease of change at building level, whilst the implemented

building components have to be easily dismantled giving attention to reversible connections methods, reusable materials and dimensioning. At material level, building products should be easy to separate to make a sustainable waste treatment possible. [1] For *existing* buildings, the challenge is to preserve and make use of flexibility of buildings when present, or to turn static buildings into buildings that can be more easily adapted tomorrow [2]. In addition, at component level, the added building solutions (e.g. partitioning, services, and building skin) need to enable dismantling, reuse and reconfiguration as far as possible. Hence, wasteful processes related with demolition of renovated buildings can be bypassed in the future. This transformable building approach therefore becomes an essential complementary keystone for the practice of sustainable renovation.

Transformability of post-war apartment buildings

The structural system, access to apartments, and organization of technical services play a key role in the flexibility of buildings. In this paper, their influence is analysed for post-war apartment buildings in the Belgian building context.

Loadbearing structure

A principal decision-making parameter in order to assess future opportunities of a post-war building is the loadbearing structure, since it strongly affects the circulation, partitioning and building skin [2, 3]. Most post-war building systems in Belgium are composed of concrete loadbearing facades, parallel cross walls and (portal) frame structures. Exceptionally, steel frame structures are found back in the residential post-war construction, like the high-rise building ‘Brunfaut Tower’ in Brussels.

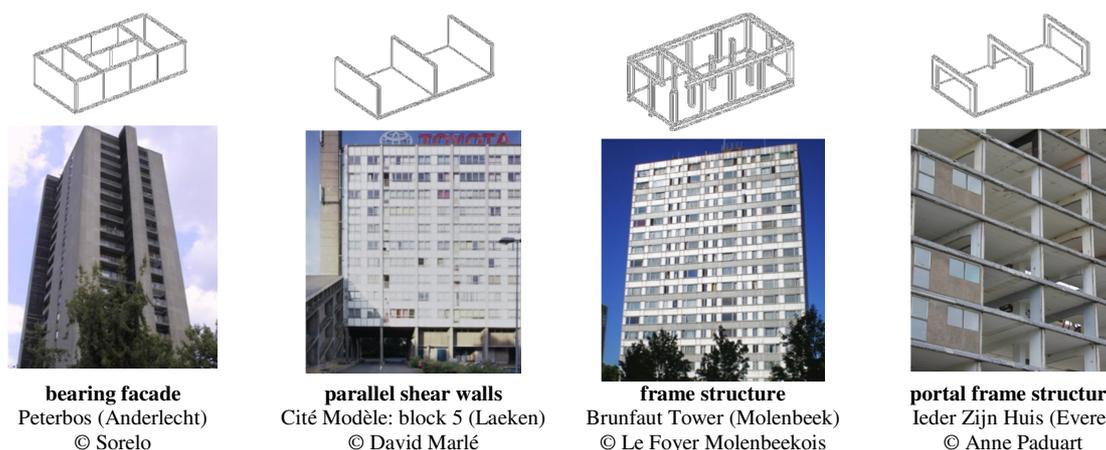


Image 1: Different structural systems can be found in Brussels' post-war apartment stock: transverse walls, combined transverse and lateral portiques (beams and columns), frame structures, and transverse portiques.

Renovation cases of today show that buildings are more flexible when the number and the dimensions of the loadbearing elements (columns or walls) are minimized - for instance using long span beams - and when they are arranged at regular spacing [3, 4, 5]. In frame structures with regular spacing and where the columns are minimized, the building plan layout is functionally liberated. The renovation of post-war buildingcases with (portal) frame structures

like 'Ieder Zijn Huis' in Brussels confirms this high degree of building flexibility. These buildings, often 'cladded' with a prefabricated curtain wall, can easily be stripped today and changed in terms of apartment configuration and building architecture. This external flexibility is important when the aim is to extend the building volume, or to add external spaces like winter balconies.

In contrast, external and/or internal loadbearing or shearing walls restrict the options to make significant modifications in the building. Large loadbearing cross walls divide buildings in parallel segments (e.g. Block 5 at Cité Modèle) and, consequently, restrict the apartment size and plan diversification. Whilst the apartment size is fixed in the latter system, the apartment rooms can possess a free plan. When a load-bearing façade is present in the structural system, the skin performance can only be enhanced by adding external or internal layers. Examples of these structural systems are frequently found in Brussels: the French Baretts and Camus systems, applied in e.g. Cité Modèle (Laeken) and Sterrenveld (Wezembeek-Oppem). The Baretts system consists of loadbearing façade elements, floor slabs and portal frames, completed with (non-loadbearing) cross walls, prefabricated staircases and vertical shafts, whilst in the Cauvet system hollow concrete façade elements are partially filled with concrete. The assembly and connection methods used in both systems (cast with in situ concrete) make it difficult or impossible to transform these buildings to today's and tomorrow's standards without making important structural interventions.

Circulation

Besides the structural system, the circulation in apartment buildings strongly influences a building's ability to reorganize spaces or to insert apartments with double orientation. Post-war apartment buildings generally applied corridor access, gallery access, and core access.

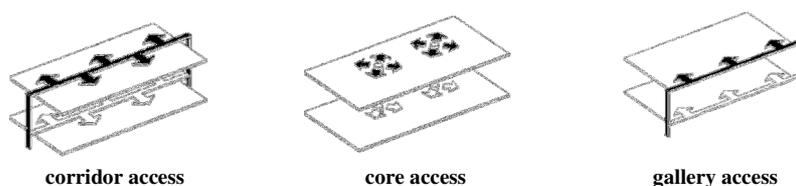


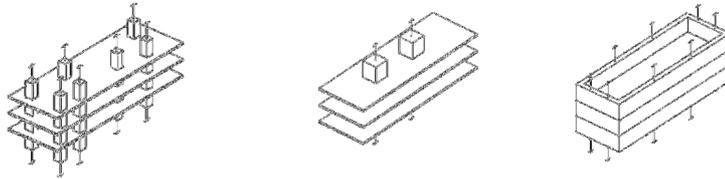
Image 2: Apartment access influences plan efficiency, and apartment size and orientation

Whilst interior *corridors* may have been cost-efficient at the time of construction - one lift and stairway suffice to make the building operational - this access type jeopardizes future comfort since natural ventilation and double orientation of apartments is hampered. An space efficient access model that allows more double oriented apartments is the core access, grouping different apartments. Finally, the gallery access is both efficient and cost-effective, while giving all apartments equal orientation and views, and enhancing natural ventilation.

Services

Post-war apartment buildings are easier to modify if loadbearing walls/columns, circulation (stairs, lifts) and technical facilities (ducts) are concentrated in functional cores. The plan

layout becomes flexible when these cores are centralized (single central zone or along the building skin), their number is minimized and they are arranged on regular spacing.



dispersed services and circulation

grouped services and circulation

Image 3: The clustering of services and circulation in central or longitudinal elements results in a high freedom of the plan lay-out [2]

Case studies

In order to formulate renovation concepts supporting future change in the life cycle of buildings, three case studies of post-war building renovation are selected in this paper: ‘Ieder Zijn Huis’ (Belgium), ‘Sterrenveld’ (Belgium), and ‘De Flat’ (Netherlands).

Ieder Zijn Huis (Evere, Belgium)

The multi-storey flat ‘Ieder Zijn Huis’ by architect Willy Van Der Meeren was inspired by Le Corbusier's Unité d'Habitation: the volume is raised by 'pilotis' with a north-south orientation. The construction principle is based on the simple stacking of porches in exposed concrete, interconnected by a grid of concrete beams, allowing a free plan configuration with a wide diversity of qualitative double-oriented apartments. The (duplex) apartments have open spaces and the few interior separations are realized by sliding walls or cupboards.

The challenge during renovation (assigned to ORIGIN Architecture & Engineering) was to adapt the building to modern standards in a narrow grid with a free ceiling height of two meters. The prefabricated façade panels could be easily dismantled and replaced during the stripping of the building since the mortar connections were weak. The open plan with grouped services and internal circulation made it easy to reinsert new apartments according to today's comfort standards with respect for the original plan layout. However, in order to meet thermal and acoustical standards box-in-box solutions were applied, negating the original plan flexibility. In contrast to the original flexible sliding walls and cupboards, the new is difficult to adapt due to irreversible connections methods and non-reusable building elements.

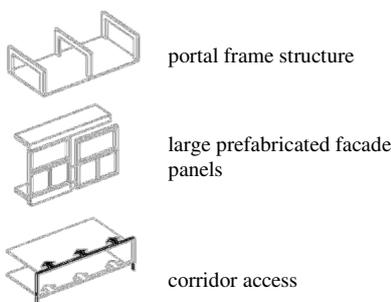




Image 4: Renovation of Ieder Zijn Huis, Evere, Belgium (© ORIGIN, © Paduart)

Sterrenveld (Wezembeek-Oppem, Belgium)

Sterrenveld, part of the garden city project ‘Ban Eik’ situated in Wezenbeek-Oppem (Belgium), required deep renovation after 30 years of inhabitation. A holistic renovation approach was embraced: apartments were adapted to current comfort standards, the living spaces were enlarged, measures were taken to reduce energy losses and minimise existing thermal bridges, whilst photovoltaic panels and sun boilers were installed. Since the original interior corridor made it impossible to add apartment typologies with double orientation, the loadbearing skeleton structure was stripped, and the vertical circulation was entirely reorganised: a new flexible space plan was created without resemblance to the initial plan layouts. Three centralised circulation groups were added, offering natural daylight in double-orientated apartments. Partitioning dry walls were introduced to minimise the loads on the existing loadbearing structure and to maximise flexibility for future interventions. Kitchens and sanitary rooms were organised along new central technical shafts. In addition, benefit was taken from the external flexibility of the frame structure. The south-west building side was stripped and an external galvanised steel structure was added to ensure the global stiffness of the building, while giving rise to local extension of rooms and creates winter gardens adjoining to the living spaces.

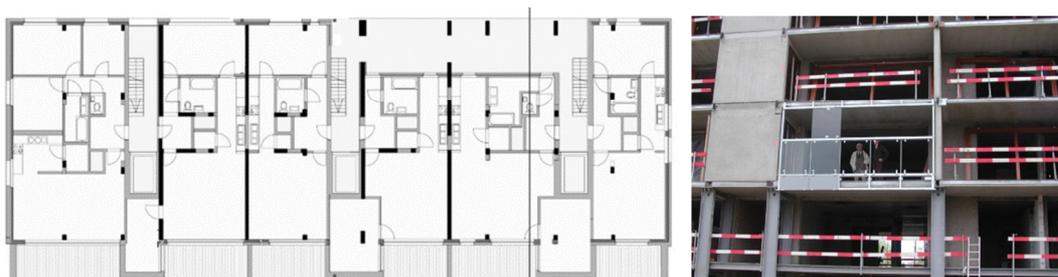
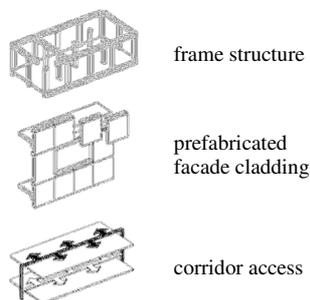


Image 5: Renovation of Sterrenveld, Wezembeek-Oppem, Belgium (© VMSW)

Sterrenveld illustrates the spatial flexibility of frame structures, that was initially hampered by an interior corridor and dispersed technical services. Its renovation shows that with a holistic approach buildings can be re-designed to comply with evolving comfort standards. A static building was transformed into a transformable building, creating qualitative and sustainable spaces not only today, but also anticipating changes of tomorrow.

De Flat (Kleiburg, The Netherlands)

The renovation of ‘De Flat’, one of the biggest apartment blocks of Amsterdam constructed during the 1960s, would require over 70 million euros to comply with today’s standards. An alternative solution was proposed to prevent its demolition: the housing corporation offered the building estate for only *one euro* to catalyze an economically feasible plan. Elevators, galleries and installations were renovated but apartments were left empty (no partitioning or services) in order to be retrofitted by future private owners.

The structural parallel cross walls generated a high repetition of equal double oriented rooms with a free internal plan. To break down these repetitive elevations adjacent rooms and stacked rooms on the upper building floors were joined by making new openings in the structural elements. Hence, a wide range of new apartment typologies could be introduced in a partially flexible building that, due to the presence of horizontal slabs in the plan, only could introduce a restricted set of monotonous apartment typologies.



Image 6: Renovation of ‘De Flat’, Kleiburg, The Netherlands

Re-design for change scenarios

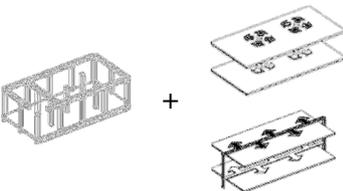
In this paper, three renovation scenarios are derived from the previous analysis of case studies with the aim of preserving and making use of flexibility of post-war buildings when present, or to turn rigid buildings into more transformable ones for the future.

The first renovation scenario consists of adding longitudinal plan flexibility to buildings that only have flexibility in one building direction, i.e. buildings with structural cross walls like ‘De Flat’. To improve the variety of apartment typologies in these buildings structural perforations (openings) need to be encouraged in cross walls and upper floors in order to make disconnected parcels communicate in all directions. Hence, larger, more diversified and flexible apartments typologies can be generated in these buildings.

In the second scenario, the internal flexibility is improved of frame structures with structural elements that obstruct a free plan, like Sterrenveld. Structural interventions like an altered vertical circulation and addition of an external steel frame offers opportunities to introduce more qualitative apartment typologies, to extend the building surface and provide better thermal and acoustical performance in general.

The third scenario supports the future adaptation of buildings that already have a high transformability. The renovation of the portal frame structure ‘Ieder Zijn Huis’ reveals that the initial building flexibility can get lost after renovation if no attention is given to new renovation methods. Focus must be set on development of technical building solutions that allow non-destructive dismantling, adaptation and reuse in order to enhance future transformability thereby fostering low life cycle waste production and material consumption.

Table 1: Summarizing table for dynamic renovation scenarios

	Post-war building types	Building level	Component level
Renovation scenario 1		<ul style="list-style-type: none"> - Structural intervention: create openings in structural cross walls - Introduce centralized technical shafts where possible - Introduce a flexible plan lay-out 	Introduce dynamic design for: <ul style="list-style-type: none"> - building skin - internal walls
Renovation scenario 2		<ul style="list-style-type: none"> -Structural intervention: adapt building circulation to avoid corridor access to apartments - Introduce centralized technical shafts where possible -In case of irregular structural system, simplify the grid of the columns and add an external structural frame -Introduce a new plan lay-out that supports future changes 	Introduce dynamic design for: <ul style="list-style-type: none"> - building skin - internal walls - partition walls
Renovation scenario 3		<ul style="list-style-type: none"> - No structural interventions - Introduce centralized technical shafts if possible 	Introduce dynamic design for: <ul style="list-style-type: none"> - building skin - internal walls - partition walls

Conclusion

During renovation of post-war buildings today, architects are challenged to unite modern aspects of life with structural and technical limitations of existing buildings. Some building



types have a good ability to introduce these required changes due to simplicity of the structural system, easy removal of outdated building layers or a flexible plan lay-out.

The analysis of the case studies of renovation of post-war buildings demonstrates how renovation measures today can improve significantly the negative image of the post-war housing estate. Transformable renovation approaches can be introduced that ensure a prolonged useful life of the building for the next decades depending on the type of structural system, plan and service organisation of the building, circulation, but also renovation budgets, vision of the architectural team, and the building architecture.

Buildings with a high transformation capacity, like portal frame structures, give architects the necessary freedom to re-create a liveable building for the next decades without many efforts. Renovation of buildings with a lower flexibility can in contrast be regarded as a challenging task to increase the future capacity of buildings to change.

Finally, in order to sustain future adaptation in transformable buildings, further attention must be given to design and development of dismountable and reusable building products as technical detailing for transformable buildings is not yet common practice in the residential building sector [6].

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Energy Efficient Refurbishment Analysis for an Apartment Building in Portugal

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Abstract: *There are many parameters that influence energy simulation outputs of buildings, some of which are analysed in this study including the thermal properties of building elements. Within the “Holistic energy-efficient retrofitting of residential buildings” (HERB), financed by the European Union seventh framework programme project, the most appropriate way of saving energy in a residential apartment building in Portugal is sought in terms of energy. This study presents the simulation results of energy efficient retrofitting strategies of the building envelope and investigates the integration of renewable energy technologies in an existing building block. The existing multi-storey residential building in Almada is first modelled by using Sketchup Open Studio plugin; the definition of building materials, HVAC equipment system and the analysis are undertaken with the EnergyPlus building energy simulation program for different retrofit scenarios. After obtaining the energy demand outputs, the renewable energy technology integration as well as PV and solar thermal system integration potentials are investigated.*

Keywords, Energy efficient refurbishment, residential buildings, building envelope retrofit, renewable technology

1 Introduction

Residential buildings account for almost 75 percent of the total EU floor space of the building stock [1] therefore energy efficient refurbishment is a key issue in residential buildings for demand reduction. Particularly, for residential buildings, conducting a building thermal efficiency retrofit is a complex decision-making process involving building owners, managers, residents, and construction industry professionals. Within the “Holistic energy-efficient retrofitting of residential buildings” (HERB), financed by the European Union seventh framework programme, new and innovative energy efficient technologies and solutions for retrofitting older buildings are established to be developed and demonstrated for the buildings in different building types, climates and socio-economic conditions in European countries. As a part of the HERB project, in this study, the appropriate ways of energy demand reduction and energy production with renewable technologies are investigated for an apartment building in Almada, Portugal. The aim of this paper is to present the results obtained to guide the professionals in this field on energy efficient refurbishment



strategies for residential buildings in southern dry climate region. To obtain this goal, firstly, energy demand reduction potentials are investigated via architectural interventions such as building envelope retrofits by using energy performance simulation environment EnergyPlus. Secondly, according to demand data obtained from EnergyPlus simulations, renewable technology integration as PV system for electricity and solar thermal system for thermal energy demand are investigated to be able to constitute a basis for further decision making on the building.

2 Methodology

This study consists of two main parts, the first of these is based on simulating and quantifying energy demand of the building which has multiple thermal zones. For the second main part, renewable energy technology integration potentials are elaborated.

3 Building Envelope Retrofit Study

3.1 Simulation Tool

In this study, first, the Legacy for SketchUp [2] which has a user friendly interface; was used for creating and editing the building geometry. Its graphic interface eases the creation of a building model, but the lack of HVAC function causes a need to use a simulation engine. Besides, Legacy OpenStudio Plug-in for SketchUp allows user to launch EnergyPlus [3] simulations. EnergyPlus whole building energy simulation program, based on the most popular features and capabilities of widely used worldwide programs BLAST and DOE-2, has the capabilities include integrated simulation, combined heat and mass transfer balance, multizone air flow, HVAC loops and algorithms from ASHRAE loads toolkit is more flexible on input, output and simulation capabilities [4].

In particular, by means of defining thermal zones and easily revising the surface properties; OpenStudio Plug-in for SketchUp and EnergyPlus are appropriate simulation tools for this study which have interoperability with each other.

3.2 Definition of the Building

A multi storey residential apartment block in Almada, built up in the early 90`s, after the first piece of Portuguese legislation regarding the energy performance of buildings [5], was investigated in this study. It is a five-story -except basement floor- brick masonry, with 1296m² total floor area, and it has cast in place concrete columns and slabs. The modeled building is a part of an apartment unit with L-plan scheme and placed in between two adjacent neighbor buildings, as seen in Figure 1. At each floor, except basement floor area without any partition walls, there are two flats each consists of one kitchen, one living room, three bedrooms (two only in one of the flats at ground and 1st floor), two bathrooms and two cellars as in Figure 2.



Figure 1 Place of the modeled multi storey residential block

The main façades are NW/SE oriented, and front elevation is oriented at an angle around $157,5^\circ$ degrees to SSE. And there is a difference of slope between entrance floor and basement floor. Main entrance floor is 1.2 m high from the ground, and there is stairs providing access to this floor. The basement floor has high windows all along the back façade and also small ones along the front façade. At the modeling phase, the topography factor and these level differences were taken into consideration to be able to have more steady simulation results.



Figure 2 Digital layouts of apartment unit; basement, ground and the other floors

At the building, each floor has two flats except basement floor, totally there are ten flats. The square meters of each flat and space functions could be seen in Table 1.

Space type	Room	length x width (m)	Area (m ²)	
Circulation area on every floor	Stairs – elevator	(4.72 x 1.1) (2.45 x 1.2)	8.13	
Basement Floor	Cellar	19.17 x 10.2	196.5	
Ground Floor 1st Floor	Flat 1	Bedroom & Bathroom	4.2 x 4.5	18.9
		Front Bedroom	3 x 4.3	12.9
		Kitchen	4.5 x 2.3	10.35
		2 of Cellars	1.2 x 3.15	3,78
		Bathroom	1.8 x 1.75	3.15
		Living room	4.35 x 3.4	14.79
	Flat2	Bedroom & Bathroom	4.2 x 4.5	18.9
		Front Bedroom	3 x 4.3	12.9
		Front Bedroom 2	2.7 x 4.35	12
		Bathroom	1.8 x 1.75	3.15
		Kitchen	4.5 x 2.3	10.35
		2 of Cellars	1.2 x 3.15	3.78
		Living room	4.35 x 3.4	14.79
		2 nd 3 rd 4 th Floors	Flat 1	Living room (2 nd 3 rd 4 th floors)
Kitchen	4.5 x 2.3			10.35
2 of Cellars	1.2 x 3.15			3,78
Bathroom	1.8 x 1.75			3.15
Bedroom & Bathroom	4.2 x 4.5			18.9
Front Bedroom	2.7 x 4.35			12
Flat2	Front Bedroom 2		2.7 x 4.35	12
	Cellar		0.95 x 1.32	1.25
	Living room (2 nd 3 rd 4 th floors)		4.35 x 3.5	15.22
	Kitchen		4.5 x 2.3	10.35
	2 of Cellars		1.2 x 3.15	3,78
	Bathroom		1.8 x 1.75	3.15
	Bedroom & Bathroom		4.2 x 4.5	18.9
	Front Bedroom		2.7 x 4.35	12
Front Bedroom 2	2.7 x 4.35	12		
Cellar	0.95 x 1.32	1.25		
Total	216 m ² each floor			
10.75 x 19.7	216 x 6 = 1296 m ²			

Table 1 Internal floor area of rooms in each floor

The thermophysical properties of existing building envelope components in terms of U-values are estimated at 0.77W/m²K (walls), 5.77 W/m²K (windows), 1.10 W/m²K (roofs) and 0.43 W/m²K (basement concrete slab floor). The building is fitted with clear single-glazed aluminium window. Building envelope components of the building could be seen in Table 2 as it is used in the simulations.

Building typology	Building Envelope	Layers	Uvalue	
			W/m2-K	Materials
Residential (4-storey)	Existing	Wall-Brick facade	0,74	Brick tile(10mm), plaster(10mm), double hollow brick(200mm) , interior plaster (10mm)

apartment building)	Wall-Regular facade downside	0,77	Plaster(20mm), doub.hollow brick(200cmm), int. plaster(10mm)
	Wall-Regular facade upside	0,74	Plaster(65mm), doub.hollow brick(200mm), int.plaster(10mm)
	Dividing walls	1,05	Plaster(20mm), double hollow brick(110mm), cement(40mm)
	Inner Walls (room-room)	1,10	Plaster(20mm), double hollow brick (110mm), plaster(20mm)
	Inner walls (house-house)	0,90	Plaster(25mm), double hollow brick (150mm), plaster(25mm)
	Inner walls (House-common area)	0,95	Plaster(15mm), double hollow brick (150mm), Plaster(15mm)
	Glazing	5,77	Glass(6 mm) Generic CLEAR
	Roof	1,10	Portuegesetile, concrete beams, ventilated loft, EPS, concreteslab
Ground Floor	0,43	crushed stone, concrete slab(200mm), floor screed(50mm)	

Table 2 Constructions used in the simulations (Energy Plus)

3.3 Existing HVAC and DHW systems

For the space heating, there is no heat distribution system in the building. According to the questionnaires with residents, it is known that in each flat an electric unit heater is used for the winter period. And there is no air conditioner in any flat, ventilation is provided naturally.

For domestic hot water usage, a gas furnace in the basement floor provides hot water for each floor centrally. Natural gas is also consumed by cooking devices at each floor.

3.4 Climate Properties

Climate of Almada is generally warm and sunny which has a monthly average temperature varying between 10.6°C (January) to 22.6°C (August). The average number of heating degree days (HDD) is 1160°C.days with a heating period of 5.3 month and about 4 month cooling period [6]. Considering the general climate characteristics of the region, the simulations were run with hourly climate data for location of Lisbon provided by EPLUS.

3.5 Model Assumptions

3D Form of the investigated building was modelled with Sketch-Up and zone definitions were made by Open Studio Plug-in which has interoperability with EnergyPlus and provides idf. files for this interface.

Each flat at each floor, also basement, roof and circulation areas were defined as thermal zones which are thirteen zones in total. And the model was defined in between the adjacent buildings as in the Figure 3.

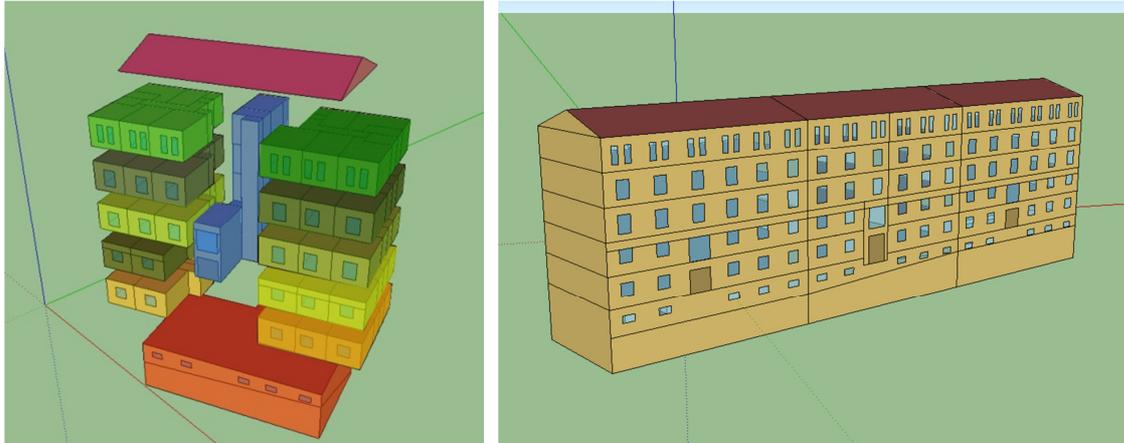


Figure 3 Thermal zone definitions and adjacent buildings in the 3D model of the Portugal building

Also via OpenStudio plug-in, surfaces were defined as -surface to surface- according to their neighborhood surface areas. Interior walls were disregarded in 3D model. However surface areas of internal walls were taken into consideration as ‘internal mass’ in EnergyPlus.

3.5.1 HVAC System, DHW Assumptions

An ideal HVAC system was defined to be able to obtain heating and cooling energy demand of the building. According to this system:

- All HVAC systems are controlled by set point temperatures, besides heating and cooling are provided in all properties by airflow systems.
- For the heating and the cooling system of the building, a high and a low set-point is used so that there is a temperature range inside the building. As a residential building, it is considered occupied everyday.
- The daytime - 7a.m. to 7p.m.- heating set-point for the building is 21°C degrees. The nighttime - 7p.m. to 7a.m.- heating set-point is 15°C. And the cooling set point is 25°C for the daytime -7a.m. to 8p.m.- and for the nighttime -8p.m. to 7a.m.- it is 30°C.
- For winter ventilation –from December to March- air change per hour is defined as 0.3 h⁻¹ for whole day. For summer ventilation –from March to September- air changes per hour is defined as 4 h⁻¹ for night ventilation –from 10:00 p.m. to 7a.m.- and for the daytime period –from 7a.m. to 10p.m.- it is defined as 0.3 h⁻¹.
- Due to the volumetric flow rate of outside air into the building, the infiltration is defined as 0.3 h⁻¹ per hour for the summer period, and 0.6 h⁻¹ for the winter period.

3.5.2 Activity and Occupancy Assumptions

A study shows that thermal comfort in residential buildings is strongly dependent on weather data, more specific on recent outdoor temperatures, so that it is defined as a result of a combination/adaptation of parameters of both the environment and the human body itself [7].

In this study, thermal zone definitions were made such as including all of the spaces in a flat or including whole of the building itself. Therefore, wet space activity levels were disregarded. Number of people living in one flat was accepted as 3 persons. And for all zones, activity levels were determined both for sleeping and working periods as well.

3.6 Case definitions

With the purpose of energy demand reduction, simulations were run based on different cases. To be able to comprehend the simulation output differences under the influence of building envelope retrofits, simulation variations were defined as in Table 3. In the first case (base case), U values of the building elements are as in the reality. For the second case scenarios, reference U values are defined based on the thermal legislation in the second half of the year 2006 [8]. Second case scenarios were run as wall refurbishment, wall and window refurbishment, wall, window and roof refurbishment; wall, window, roof and ground floor refurbishment respectively.

For case definitions, the building materials were assumed to be changed with the ones which have better thermal conductivity. Hence, there is no connection between the use of space definitions.

Construction name	U value W/m ² -K		
	Base Case - BC	Reference values*-R1	Passive house standart-R2
Wall	0.77	0.70	0.13
Window Uvalue(g-value)	5.778 (0.80)	4.30 (0.81)	1.4 (0.51)
Roof	1.10	0.50	0.13
Ground floor	0.43	0.4	0.23

Table 3 The Layout of U values for refurbishment scenarios *Reference values are based on the thermal legislation in the second half of 2006 [8]

Simulation Name	Which scenario has been applied to building?			
	Wall	Window	Roof	Ground floor
BC	BC	BC	BC	BC
1	R1	BC	BC	BC
2	R1	R1	BC	BC
3	R1	R1	R1	BC
4	R1	R1	R1	R1
5	R2	BC	BC	BC
6	R2	R2	BC	BC
7	R2	R2	R2	BC
8	R2	R2	R2	R2

Table 4 Simulation scenarios according to refurbishment cases

3.7 Results of the Simulations

According to different simulation cases, energy demands per square meter, followed from the annual simulation period, could be seen as in the Table 5 below. End uses for each case were recorded in kWh. The results are presented in the following paragraphs by comparison of the results of reference U values and passive house standard U values.

Demand type	Energy demand per m ² according to scenarios (kWh/m ²)							
	BC	1	2	3	4	5	6	7

Heating energy demand	11.4	11	9	8.9	8.4	6.8	5	4.5	4
Cooling energy demand	15.4	15.5	16.2	15.4	15.9	16.3	12.8	12.7	12.4

Table 5 Annual energy demand outputs per square meter

3.7.1 Simulations with reference U values

As it could be seen in the Figure 4, not in a vast scale even so, heating energy demand decreases with the energy efficient refurbishment of the building envelope. And cooling energy demand has not a big change.

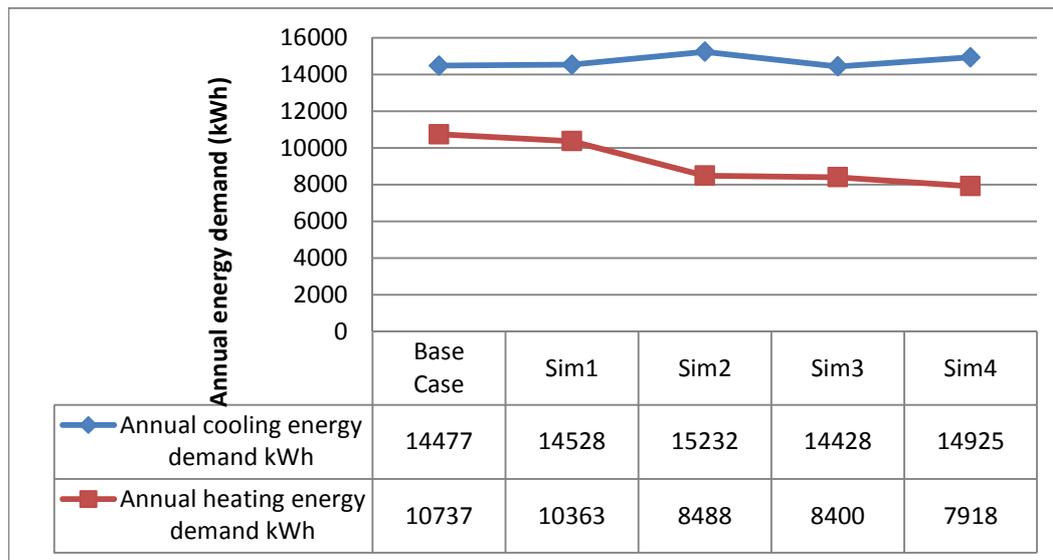


Figure 4 Simulation results with Reference U values

3.7.2 Simulations with Passive House Standard U values

As it could be seen in the Figure 5, compared to demand prior to refurbishment, heating energy demand decreases about %64 and cooling energy demand decreases about %19 after the whole energy efficient building envelope refurbishment.

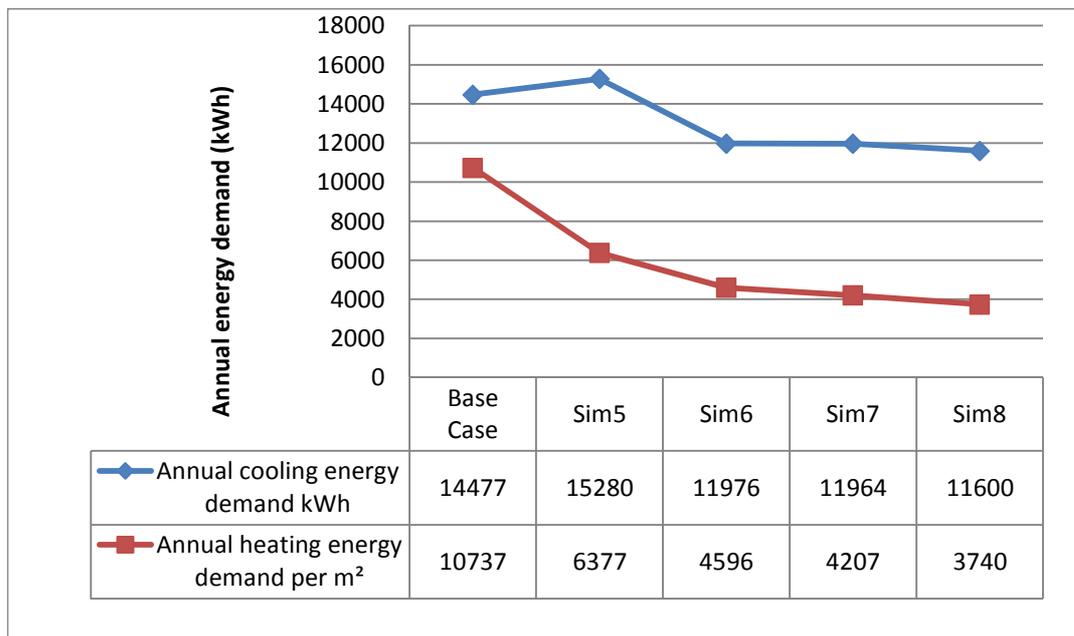


Figure 5 Simulation results with Passive House Standard U values

4 Renewable Energy Technology Integration

4.1 Solar Thermal System Simulation

Solar thermal simulation study was done by using the model developed within the HERB project which provides an improved understanding of the influence of the operational parameters (solar light intensity, wind speed) on the performance of solar based renewable energy systems.

The mathematical model was combined in the simulation environment Insel [9]. Heat source was attached to the thermal system model and was calculated with input data set received from the EnergyPlus simulations of the building energy demand. Also, meteorological data such as e.g. ambient temperatures, global radiation etc. as well as geographical data for solar thermal simulations and the Insel calculations allow choosing the appropriate design as well as the prediction of the performance of the selected heat source.

The following simulation result shows a thermal solar system with 90m² absorber surface designed to cover 50% of the heat demand in winter time for the Almada building. It could be seen that the solar thermal system could achieve the goal but due to huge surplus in summer most likely would not be an economical solution.

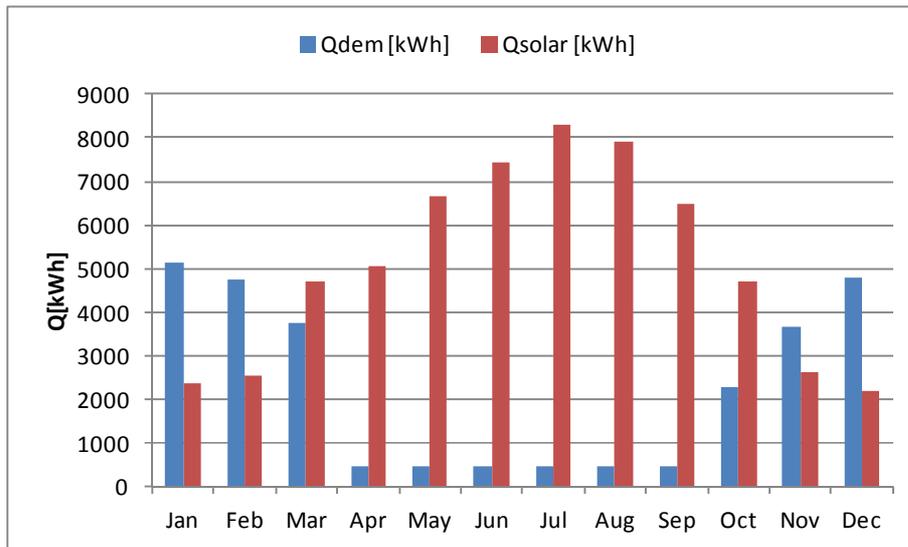


Figure 6 Monthly simulated energy delivery of a 90m² solar thermal system in Almada Portugal in comparison to energy demand values obtained by EnergyPlus simulations.

4.2 PV System Simulation

As such in solar thermal system simulation, PV system simulation was performed by the model developed within the project. The developed PV-models in analogy to the thermal systems were integrated into the Insel-Simulation platform, where the model could be fed by ambient parameters such as irradiation, wind speed, ambient temperature etc. and if wanted connected to electricity demand data received from the building simulation by e.g.

EnergyPlus. Then, calculations and validations were carried out for the case study building in Almada, Portugal.

For determining the performance of a PV system for the Almada building, it was considered that the whole roof area of the building would be used for a free standing PV-installation parallel to the roof inclination. This resulted due to building orientation and tilt of the roof in a system with two PV-fields with for this example chosen 44 Sunpower SPR-305-WHT panels each, one oriented to SSE and the other to NNW with a tilt angle of 21°. As an inverter the REFUso1 013K was selected. As input files geological data latitude (38.73 and longitude 9.15) of Lisboa were used. The weather data before generated in EnergyPlus for building energy demand simulation and the before mentioned thermal supply calculations served as the basis for the performance analysis of the suggested PV-System.

Each PV field was arranged to 4 strings of 11 PV-panels each which are connected to one inverter (Figure 7). The total of both collector fields amounts to 88 panels and two inverters with a nominal power of 26,9 kW and a power ratio of 1,08.

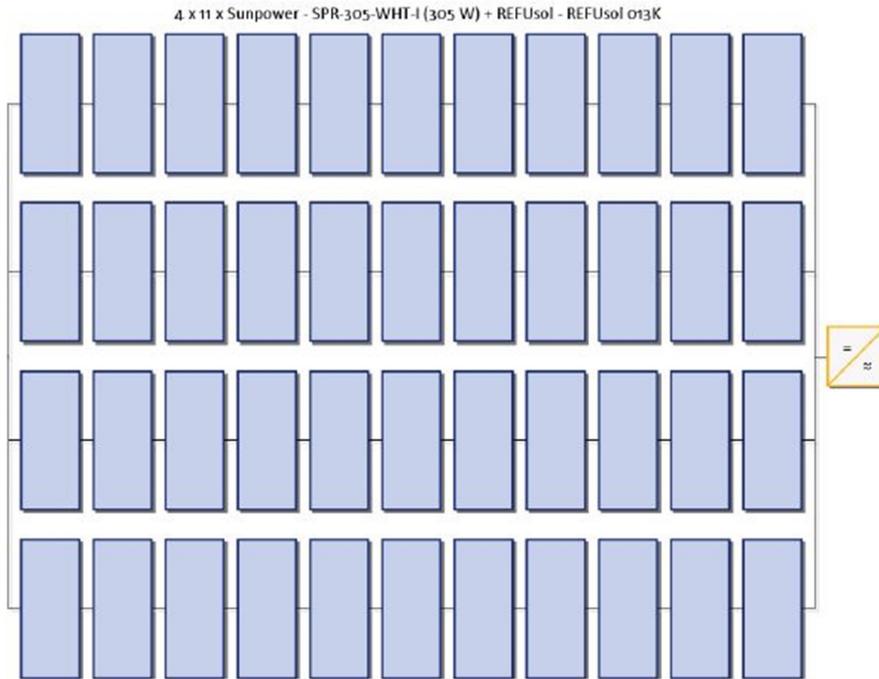


Figure 7 Wiring diagram for one PV-field

Figure 8 shows the average monthly performance ratio of the two fields (SSE and NNW) in comparison. It could be seen that the performance ratio differs in the winter months due to the unfavourable tilt angle of the NNW field, whereas in the summer months the two fields perform equally.

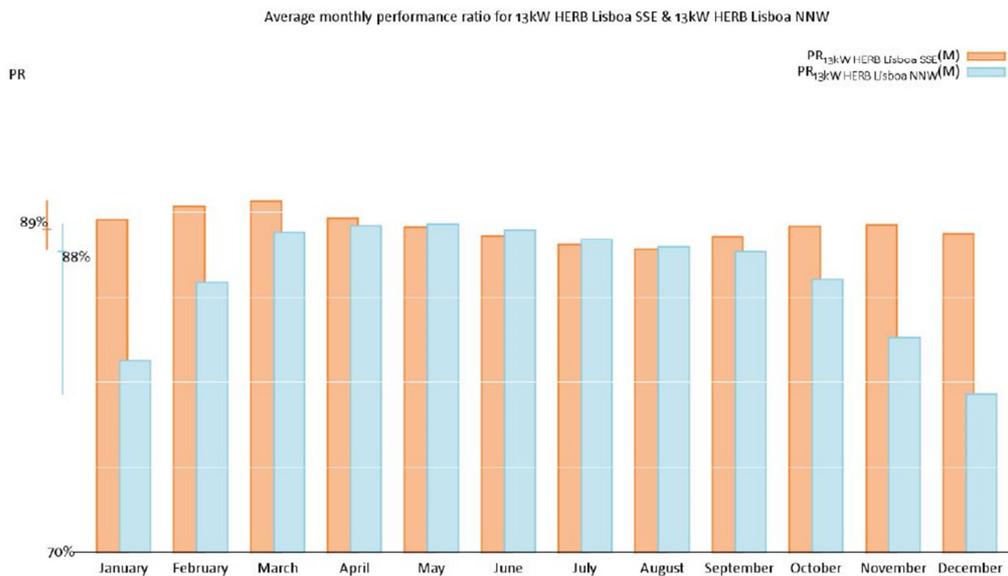


Figure 8 Average monthly performance ratio SSE and NNW



5 Discussion

As a result, it could be shown that despite the low quality thermal envelope properties of the building, the heating demand is rather low at 11 kWh/m²a. Improving the building standard reduces mainly the heating demand even further down to 4 kWh/m²a. In warm climates, it is more significant to reduce the cooling energy demand primarily considering thermal comfort conditions, instead of heating energy demand. And results of the simulations have shown that the cooling demand is not much influenced by the building thermal quality, depending mainly on the internal load and sun shading strategy. By means of whole refurbishment, results show that compared to cooling demand prior to refurbishment, cooling energy demand decreases about %19. It is likely to save high amount of energy, however, from the economical point of view, it may not be cost effective to retrofit all of the building envelope elements in the present case.

With the given low demand scenarios, it could be shown that renewable energy integration is more efficient in terms of primary energy savings and costs. 90 m² of solar thermal collectors contribute to 50 % of the building thermal energy demand. The addition of 140 m² of NNW and SSE oriented photovoltaics provides 119% of the building electricity demand.

Depending on existing energy supply structure and the fact that refurbishment measures have to be carried out on inhabited flats and/or buildings, even more efficient measures had to be substituted by more viable ones. So, for example the Portugal multi floor and multi flat building had no fluid based heating infrastructure (heating by flat based, decentralized electrical heaters), which would make the introduction of a e.g. centralized solar thermal system for heating and domestic hot water preparation most difficult and a PV system more convenient. The integration of PV-systems seems to be a strategy to decrease primary energy demand significantly without severe interference of the residents.

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Tackling climate change at community level: the example of Geothermal Communities project in Montieri (Italy)

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Abstract: European Union is striving towards energy transition in favour of renewable resources and smart management systems for urban environments. Major cities are generally seen as the main focus of research for implementing innovative solutions, because the environmental problem is more evident there. Local communities, such as small historic towns of Italian territory, demonstrate to have higher potential of success in renewable energy transition than medium and large size Italian cities. This is due to the availability of large amount of natural resources in their territories rarely exploited in a sustainable and organised way.

The paper analyses the main factors characterising the birth of energy communities at European level and introduces the case study of Geothermal Community project in the Municipality of Montieri to express limits and potentials of undertaking community energy actions in Italian small historic towns.

Community energy, small historic towns, renewable energy resources, local actions

Introduction

By the 20/20/20 European Strategy the European Union has paved the way towards the development of a low carbon society. The European Union is developing specific path for urbanised areas such as the implementation of the Smart City and Communities Stakeholder Platform to achieve social, economic and environmental objectives. Main targets of the platform are European cities and urban communities, where three quarters of European population lives and the 70% of energy consumption and green house gasses emissions occurs. Despite the European interest for cities, several studies demonstrate that the community level is a good scale for implementing renewable energy integration [1] [2] with the aim of tending towards energy autonomy. Isolation of communities is seen as an advantage for implementing 100% renewable energy choices [2]. Literature review demonstrates that the transition to a low carbon society requires a shift from centralised energy system based on fossil fuel resources to a decentralised production and delivery based on a combination of several renewable resources [3] [2]. The scale of the system become fundamental: to approach energy autonomy objective is necessary a balance between demand and supply, the smallest the first the smallest are the investments and the amount of renewable systems to be integrated in the territory. Small-scale actions favour participation of local inhabitants as main stakeholders and managers of their own sustainable development.



In Italy small old towns may be the right scale for community energy implementation because of the favourable scale factor represented by low urban density (hence energy demand) and of the potential resources present in their natural territories.

Community energy is the term used to indicate a form of energy management led at community level. It involves citizens as active stakeholders in the multiple areas of energy production, delivery and consumption [4]. In general terms a community is identified by sense of place, identity, localism and shared value. In community energy the term is strictly connected to the local territory and resources availability and how local stakeholders manage it. [2] Community energy represents a local geographic entity with which an actor is potentially associated [5]. Recognised benefits related to local energy projects for generation and distribution of heat and power are mainly the increased security of supply, reduced environmental impact and economic one, derived from the sell of extra power produced [2].

Recent years have seen a successful development of a range of small-scale renewable energy systems (RES) over Europe. A leading country in community shared RES is Denmark where 80% of wind power capacity is owned by local partnerships. The energy policy of Germany is also driving local decision makers to undertake community projects. From Germany are very well documented examples of 100% renewable communities such as the town of Freiamt, that has achieved 100% renewable power generation with a mix of several resources [4], and the action undertaken by the community of Feldheim that has achieved full 100% renewable energy production through measures managed by local farmers and inhabitants.

In Italy the transition towards renewable energy is mainly following the same framework of fossil energy. The general trend is, in fact, the development of large production sites that distribute energy through existent energy grids. Large power or heat generation plants are installed and companies pay royalties to local administrations for the exploitation of the resource. The mechanism works well for both companies and administrations from economical point of view but due to the large scale, it limits the potential for bottom up actions and energy autonomy of communities. Another phenomenon under development both in Italy and in Europe is that cities are looking at their surrounding territories as reservoirs for renewable energy system installations to satisfy urban energy demand. This represents a threat for landscape preservation of territories because the large energy demand implies extensive installation of RES systems that eventually generate an impact on the natural environment. Nevertheless there are some Italian best practice examples of renewable energy system integrations that take into account local resource potentials and involve local communities. A study promoted by the municipality of Comunità di Castello (Perugia) outlined a potential scenario for energy autonomy of an area of Umbria Region called Alto Tevere Umbro [7]. The analysis demonstrated that a mix of several renewable resources would lead to 100% production of electricity and heating. The energy transition would be able to generate incomes and to attract investors for developing manufactural activities on the area. The scale of intervention should be directly linked with local development favouring small and diffuse plants managed by local communities. An Italian example of best practice is the



small town of Varese Ligure that at the end of the 90s started a process of transition towards low carbon energy status through several initiatives that involved different spheres of sustainability. To implement the energy transition that led to the “CO₂-free town” public recognition, the municipality firstly involved a local small medium enterprise (SME) in the installation of two wind turbines. In few years were added other two turbines with the financial support of a bigger company. The power production was also integrated with diffuse photovoltaic arrays and small hydropower units. The municipality with the involvement of local cooperatives installed other RES such as solar thermal systems. The strength of the process was the involvement of local population through awareness campaigns and active participation in local initiatives [8].

In Italy there are few large cities and many medium and small towns. Of the total 8101 municipalities, 5868 are characterised by a population under 5000 inhabitants. [9] A large part of the Italian territory is characterised by hills and mountains and has a quite low density of population distributed in municipalities that own large areas of natural land. Almost all Italian cities and towns have well kept historical centres. Of the total municipalities, 6850 are defined small historic towns. [9] During the second half of the XX century a large part of Italian small towns were subjected to a deep decline. The majority of local population moved towards bigger cities where more services and better job opportunities existed. Also production activities moved towards areas better connected by the main transportation systems. This situation on one side led to abandonment of old urban areas and natural territories with consequences on urban decay and general economic depletion, on the other side it maintained untouched the historic value of settlements, avoiding large urban expansions on the virgin territories. This second factor nowadays may be seen as an advantage in the development of bottom up organisations of resource management. In fact for small historic towns the energy transition towards renewable resources may represent a favourable choice not only for environmental improvements but also for the opportunity of generating local development and jobs and to attract investments.

Methodology

The paper reports the lesson learnt from the experience of the Municipality of Montieri that in 2008 started a process for the exploitation of high temperature geothermal resource present in the territory with the construction of a district-heating network for the town centre. Since 2010 the municipality have taken part in the Geothermal Communities project that integrated initial objectives with solar energy systems and with the management of the energy demand on historic dwellings. The peculiarity of the project is the realisation of a big public work for a small community and the fact that the municipality is a valuable medieval settlement, whose history and survival has always been connected with the resources of the territory. The case study and its results are expressed through the structure of key issues characterising the energy autonomy in sustainable communities proposed by Rae and Bradley in [2], in order to put this local experience in relation to the general European trend in energy community developments.



The community of Montieri

The Municipality of Montieri counts 1250 inhabitants on an area of 108.61 km² in the zone of Colline Metallifere in Grosseto province of Tuscany Region. Population density is about 11.5 inhabitants per km². The population is subdivided among four villages: Montieri, the chief town, with its 435 inhabitants and three hamlets, Boccheggiano (498) Gerfalco (139) and Travale (178). There are in total 616 families with an average per household of 2.03 members. The 2001 census (10 years lag) showed a reduction on number of inhabitants by 16.68%. The chief town of Montieri, where the Geothermal Communities project takes place is a small historic village, its urban development begun in medieval time because of the presence of copper and silver mines and its political and economic destiny was always linked to the exploitation of territorial resources.

Project financing

Montieri was one of the last municipalities of the territory that owned a geothermal well and hadn't exploited it yet for thermal energy generation. Among the four hamlets making up the municipality only Montieri can benefit of the geothermal district heating project because of the short distance of the urban centre from the geothermal well. The construction of the district heating has been possible by a combination of public and private funding. Public funding are about 45% of the total cost of the works and are subdivided as follow: national co-financing 46.2%, EU funding 28.59%, municipal funding 10.8% and regional funding 14.42%. Private funding corresponds mainly to the bank loan asked by the municipality that will be pay out mainly by costs that incur for dwelling's connection to the network and first years heating and DHW bills. The initial cost of the service will be high for citizens but will drop as soon as the loan is payed out. ENEL Green Power, the energy group company that in Larderello area manages the geothermal resource for electricity production, yearly pay the royalties to the municipality for the exploitation of the resource that will contribute to reduce the loan as well. European Union funds are provided by the participation as beneficiary member to CONCERTO initiative (FP7) through the Geothermal Communities project (GEOCOM). The project aims at demonstrating the best available technologies in the use of geothermal energy combined with innovative energy efficiency measures and integration of other renewable energy resources in three different European pilot sites located in Hungary, Slovakia and Italy respectively. The Italian project has three main objectives:

- The realisation of a highly innovative, brand new geothermal district heating system network for the historic town centre
- The energy retrofit of selected dwellings among the building estate of Montieri town centre and its three hamlets (Boccheggiano, Gerfalco and Travale)
- Solar renewable systems integration such as 42,5 m² of solar collectors for sanitary hot water production and 8.5 kWp grid connected PV panels



The degree and scale of energy autonomy

The geothermal district-heating network is being built in the historic village of Montieri where since fall 2014 will serve 425 dwellings for a total volume of 111000 m³. The total power installed is about 6100 kW [10]. The district heating will cover the full heating and hot water energy demand of the town centre with renewable geothermal resource. Dwellings will be progressively connected to the network: at October 2014 about 200 units will switch on the system.

The plant is fed by the geothermal steam and from heat recovery from the so-called 'bifase' fluid that is released during power production. Fluids are collected in the circuit of pipeline that connects the geothermal well to the local power plant. The district heating plant is made up of three main closed pipelines that cover a distance of about 5 km and an altitude gap of about 200 mt. The first circuit takes the geothermal fluid from the extraction well's circuit to the heat exchanger A; the second circuit connects the heat exchangers A and B with an insulated pipeline that takes over-heated water for a distance of 2200 mt; a third circuit subdivided into several branches takes the heated water to the dwellings of the city centre. The temperature of the water drops at every step of the circuit. The technical solution implemented represents a cutting edge technology employed for the first time in this sector.

The photovoltaic array foreseen by the Geothermal Communities project will be installed on the roof of the heat exchanger plant A of the district heating system. The location was chosen because of the distance from the historic town and the low visual impact on the landscape. Its size is sufficient to cover part of public lighting energy demand.

Demand side management

Geothermal Communities project required the integration of energy retrofit measures on the built environment in order to reduce global energy demand.

Montieri is a medieval village that still preserves historical characteristics of local old architecture. The town centre is made up of narrow paved streets sided by two/three storey buildings made up of stone and brick masonry. Some very old buildings are recognisable among the urban texture because of stone masonry walls and peculiar arches and openings. Local authority for cultural heritage and landscape listed those buildings as symbols of culture and history of Montieri. In the historic area a relevant portion of buildings needs to be renovated, in some cases critical decay is visible. In order to set suitable energy retrofit measures for old building envelopes a study was developed in [6] with the aim of preserving historical character of fabrics with the implementation of refurbishment measures. The scenario of retrofit intervention defined in [6] reveals that integrating energy efficiency measures tailored on the characteristic of historic buildings can lead to a minimum reduction of total energy demand in the village. The energy saving is estimated as a progression according to the percentage of buildings that undertake retrofit measures: the reduction is



about 3%, if just 5% of dwellings undergo renovation works, up to 20% if at least the 30% of buildings is retrofitted.

Social and economic factors

The construction of the geothermal district-heating network was strongly requested by local population because the presence of the geothermal resource has always represented an opportunity for local development since the beginning of XX century. In Larderello area the exploitation of geothermal steam for electricity production started already in 1904 with the lighting up of the first bulbs. The power production started in 1972 as answer to the oil crisis issue. Geothermal energy has always provided local job opportunities as well as economic development for activities and services of the area, otherwise mainly based on agriculture. The towns of the area that benefit from geothermal district heatings from several years, obtained low cost energy bills and very good level of comfort in dwellings. The security of supply and the winter comfort were the major motivations that convinced Montieri's inhabitants towards the development of the district-heating project.

All these factors were crucial for the public acceptance of the investment, of the initial cost and of the inconveniences related to the excavation occurred in the narrow town streets during the construction process. Moreover the installation of the pipeline was the occasion for the renewal of all urban services such as water main, sewer, electricity and other urban grids. The long working phase meant temporary disruption of services and difficulty in the pedestrian mobility, which for a population mainly made up of over 60 age persons may represent a difficulty.

Discussion and conclusion

The experience of the Municipality of Montieri presents some differences from other examples of community renewable energies in Europe. In Montieri the exploitation of the geothermal resource entailed too expensive and cutting-edge technologies to be fund and managed by a bottom up citizens' organisation. The community was involved in the geothermal district-heating project since the very beginning with surveys to assess the common interest, but the design and construction process, due to the financial and technical importance of works, was driven by the local authority through traditional (and complex) public administrative processes. The community was constantly informed of the stages of the process and a specific office was open to deal with private-public issues. The participation of the community increased with Geothermal Communities project in which, in order to implement the final equipments of the network, the dwellings' heat exchangers, citizens autonomously arranged a common purchase group. It can't be stated that local inhabitants own and manage the geothermal resource, nevertheless, if one identifies the community by inhabitants plus local authority, the project can be assumed as a community energy case.

Policies aiming at facilitating community renewable energy should consider prevailing local and institutional conditions. The actors addressed for the implementation may be of various



types as well as their interests. [5] This is especially true in the case of Montieri municipality. The project for the construction of a geothermal district heating received wide acceptance by local population even if it included large investments, urban services disruptions and long lasting excavations sites. Motivation of this support is mainly the security of geothermal heat supply and a future reduction of energy bills. The environmental protection and the CO₂ emission's reduction instead are not among motivation factors. This fact explains the low interest that homeowners had towards incentives for energy retrofit measures that were made available by the Geothermal Communities project. In fact a large part of local inhabitants weren't willing to pay for further building works on same dwellings to be connected to the geothermal district heating. According to Parag Y. et al. [3] the implementation of actions depends on both flow of information and financial incentives without a preponderance of one factor on the other. In particular the acceptance of energy efficiency measures for buildings imply a good level of awareness on final consumers of renewable energy. The lack of awareness of local population was also accompanied by the financial difficulties of the municipality that, due to the national norm for regulating local authorities' expenditures (the so called Patto di Stabilità), further limited the public investments on solar resources. This has led to the installation of the photovoltaic system only, leaving the solar thermal project to an uncertain future application.

Rae C. and Bradley F. in [2] state that demand side management is one of the key issues that need to be further explored by research activity, above all about the way it could directly affect energy autonomy in a community and about which would be the related effects on social and economic aspects of actions undertaken. In this sense a further aspect that derives from the lesson learnt of the project in Montieri is that in Italian small historic towns it is necessary to combine actions for improving energy efficiency of building envelopes with general maintenance measures. In fact in small historic towns availability of financial resources for refurbishment and restoration activities is never enough due the number of issues related to old historic building (structural, aesthetic, energetic, etc.). This integration of purposes would lead to face several problems at one time and to implement an overall approach able to enhance not only energy efficiency issues but also the valorization of tangible heritage architecture with positive consequences on economic and touristic sectors too.

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Session 101:

Towards a shared definition of nZEB? (I)

Chairperson:

López, Fabían

Societat Orgànica



Sustainable Master Planning for the 21st Century: Metrics, Tools and Processes for Achieving Net-Zero College Campus Design and Operation

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Abstract: *Colleges and universities across the United States are undergoing significant transformation toward a more sustainable educational model by fully incorporating sustainability into academic curriculum by greener building construction and more efficient campus operation. This momentum creates a rare opportunity to modify higher education and transform the US workforce and economy to a more sustainable operation.*

The new template for a sustainable college campus is geared toward increased energy efficiency and reduced CO2 emissions, incorporation of large scale on-site renewable energy and building retro-commissioning that should help achieve net-zero campus operation. Sustainability-minded colleges and universities are increasingly participating in ACUPCC (American Colleges and Universities President's Climate Commitment) while simultaneously implementing LEED and STARS Sustainability Rating Systems.

This paper reviews three case studies of campus sustainable master plans completed in the Midwest between 2006 and 2013. The tools, processes, and sustainable strategies are discussed to inform other professionals pursuing similar goals.

Carbon, Campus, Climate, College, Emissions, Net-Zero, Sustainability, University

Opportunity for Global Transformation

It is evident that the community colleges and universities across the United States are undergoing a significant transformation toward a more sustainable model of education and campus operation. Many higher education institutions are attempting to fully integrate sustainability, environmental issues and on-site renewable energy systems training into their academic curriculums, while simultaneously increasing standards and requirements for more sustainable and energy efficient building design, construction and overall campus operation.

This momentum creates a rare opportunity for university and college planners, architects, engineers, educators and administrators to fundamentally improve their current academic format and transform both the higher education system and its existing campuses.

Consequently, they may also be able to bring the existing US workforce, industry and economy to a more sustainable model of operation.



Sustainable Campus Master Planning

The new template for a sustainable college campus master planning process refocuses on increased building energy efficiency based on clear energy use targets developed early in the design process using building energy modelling, national and regional predicted energy use benchmarking. They also incorporate tracking and planned reduction of overall CO₂ emissions, installation of large scale on-site renewable energy systems, existing building retro commissioning, campus-wide daylighting and LED lighting and similar sustainable technologies and strategies aiming at achieving eventual net-zero, off-grid campus operation.

Most of the new campus design concepts feature holistic integration of various building systems into ongoing educational process, using sustainable building features as a “teaching tool” to educate building occupants, visitors and the wider community about the benefits of sustainable and environmentally conscious design. The new educational model offers a range of programs including renewable energy training for various labor trades that provides hands-on experience on photovoltaic and wind turbine installation as well as graduate MBA programs focused on corporate sustainability and environmental stewardship.

A few years back, many of the higher education institutions signed the American College and University Presidents’ Climate Commitment (ACUPCC) [1], which required annual tracking and planned reduction of their overall carbon footprint. As the current number of signatories reached 684 institutions nationally, many participating colleges and universities are faced with a significant dilemma: if unchecked, needed campus expansion and building modernization would increase their existing building area and in turn, simultaneously increase overall energy use, long-term energy and maintenance costs and related carbon emissions. This realization opened the path to tighter integration on previously not closely related areas of academic training, programming, building design, energy use and campus operation, which often had competing or mutually conflicting goals.

This paper will briefly review three campus case studies to illustrate how similar issues could be addressed through sustainable master planning process. Campus architects and planners engaged with all three institutions devised a holistic sustainable master plan process specific to each institution to address facility, energy and academic needs. The case studies also showcase evolution in approach and thought about sustainable campus master planning and operation. The new sustainable master plan models incorporated the institutional sustainability plan into traditional master planning process, as well as ACUPCC required climate action plan goals. Resulting hybrid approach evaluated and proposed technologies and tactics designed to improve campus-wide energy efficiency, reduce greenhouse gas emissions and firmly integrate sustainability into campus operations and the academic curriculum.

Carbon Footprint Inventory

Participation in ACUPCC requires detailed greenhouse gas (GHG) accounting, which describes the way to inventory and audit GHG emissions produced by the reporting entity. The accounting of GHG generates data used to create annual GHG inventories. Educational



institutions can use GHG inventories for a variety of reasons: to better understand the sources and trends in CO₂ emissions on their campuses, as well as to plan how to mitigate and reduce them through proper building design and construction. GHG emissions are calculated and reported over a 12-month period, as is standard practice, while climate action plans are devised to eliminate GHG by a given date, selected by each participating institution.

A greenhouse (GHG) inventory is a process of accounting for all GHG emissions resulting from a university or community college's operation. All emissions data is reported in metric tons of carbon dioxide equivalent (CO₂e). The emissions data is further analyzed and categorized based on source and scope.

Energy Data Collection Methodology

In addition to creating and tracking detailed GHG inventory, individual buildings within the master plan were being designed using energy consumption values calculated based on two key parameters: Projected Energy Use Intensity (EUI) and Lighting Power Density (LPD), which were compared to applicable codes and national and regional energy use averages.

Projected Energy Use Intensity (PEUI) for each project was established as a design goal, or determined from actual building energy modelling data. A project's building energy model will output predicted energy use from all available energy sources: electric, natural gas, utility provided steam, hot water, chilled water, geothermal, solar power, etc. Different energy use units are converted to kBtu/year which is then divided by gross square feet (GSF) of the building, to determine the Predicted EUI values in kBtu/sf/year.

This was an important measure of embodied energy, and an important part of calculating and predicting future carbon footprint. When available, regional data is more applicable to a given climate or a project type and as such is always preferable to national data. Sources which may be referenced for regional data by project type and location include combination of US EPA Energy Star Target Finder [2], 2030 Challenge target tables [3] including U.S. Residential Regional Averages, Canadian Commercial Regional Averages, and Canadian Residential Regional Averages, Commercial Building Energy Consumption Survey (CBECS) 2003 consumption and gross energy intensity data by climate zone.

Lighting Power Density (LPD) values were included in the calculation because of the impact of lighting choices and design on building EUI. While Lighting Use Intensity (LUI) is a more meaningful prediction of how lighting contributes to overall energy use in a building, LUI can only be derived from energy modelling. The LPD reduction goal is 25% reduction from ASHRAE 90.1 2007 requirements, which seems to be fairly easily attainable.

Case Study 1: Moraine Valley Community College – Tinley Park Campus

In 2006, Moraine Valley Community College (MVCC) passed an \$89 million referendum to increase their overall campus area square footage by nearly 33 percent. Though it would pursue sustainability goals wherever possible, the college identified its new Tinley Park campus as the location for its first and only LEED-Platinum certified academic facility. The



facility was envisioned as a driver of the MVCC’s sustainability movement, and it needed to be completed on a standard construction budget. The standard construction budget of \$10 million USD was augmented by additional funding for geothermal system and LEED-based design, totaling approximately six percent cost increase, most of which was supplemented by grant funding. Proposed on-site renewable energy system, a 52kW roof based photovoltaic array was considered, but eventually not pursued due to the length of estimated payback.

In addition to traditional planning, design and engineering, the architects identified and secured more than \$517,000 USD in grant funding. The grant money helped fund LEED-Platinum certification and building commissioning fees, as well as half of the additional cost to install a geothermal heat pump and well system. The grants also halved the payback time, sped up the approval process and allowed better and more predictable energy use results.

The geothermal system alone reduced heating and cooling costs by 32.7 percent. Thirty-six 320-foot-deep geothermal wells stored summer solar energy absorbed by the building into the ground and made it available to provide supplemental heating during winter months. Combined with the proper building orientation—the building mass is elongated along an east-west axis and faces south and north for maximum daylighting - installed geothermal heat pumps also transfer the absorbed sun energy between the building’s “warm” south and “cool” north sides without using the geothermal field. Result: the building literally heats and cools itself at virtually no additional energy cost.

To make things easier to operate, an individual heat pump serves each office and classroom. Almost all the HVAC equipment is located above or along the central corridor for easier access and fewer disruptions. Required filter changes or repairs only affect one room at the time, since each space has separate controls. Occupancy sensors and carbon dioxide (CO₂) monitors in each room detect the rise in CO₂ and heat, cool or ventilate the space accordingly.

While MVCC was not a signatory of ACUPCC at the time when Tinley Park campus was conceived, the broad application of energy efficient design strategies helped reduce overall building energy and carbon emissions by 35 percent, offering valuable insights for future use.

Case Study 2: Joliet Junior College – Joliet Campus

In 2009, Joliet Junior College took a significant step in setting sustainability goals by committing to the ACUPCC Compact and Illinois Climate Commitment Initiatives. These agreements represent the promise of higher education institutions taking the lead in reducing greenhouse gas emissions, achieving climate neutrality, applying a broad range of sustainable practices and integrating sustainability into college curricula to ensure that future generations are equipped with the knowledge necessary to be environmentally responsible.

Historically, sustainable practices have been an integral part of JJC’s culture: beginning in the 70s, the College followed procedures using the highest efficiency light bulbs available, as well as using solar panels. In 2010, various sustainability initiatives and practices culminated in the implementation of JJC’s Sustainable Master Plan, which included six buildings



designed according to US Green Building Council’s (USGBC) Leadership in Energy and Environmental Design (LEED) green building design standards.

Since 2009, JJC has made a number of significant accomplishments, such as the addition of several new buildings on its main Joliet Campus. While the six new buildings doubled the campus building area, campus wide implementation of daylighting harvesting, geothermal heating and cooling and better energy monitoring systems helped keep energy use and carbon emissions in check, even reducing their values over time.

The JJC’s Climate Action Plan sets goals for future action and develops a timeline for goal achievement. In order to determine the initial level of impact, an inventory of greenhouse gas emissions (GHG) was conducted for fiscal years 2009-2010 and 2010-2011. Through this, strategies were developed to address the most significant sources of GHG emissions. Incorporated with these strategies are educational efforts intended to promote awareness about climate change and carbon emission throughout the College.

2009 - 2010		2010 - 2011	
Total area: 796,800 sq. ft.		Total area: 1,147,000 sq.ft.	
Total enrollment: 10,709 (FTE)		Total enrollment: 10,802 (FTE)	
Scope 1 Emissions			
Stationary Combustion	2,419.0 mT of CO2e	Stationary Combustion	3,139.0 mT of CO2e
Mobile Combustion	738.0 mT of CO2e	Mobile Combustion	867.0 mT of CO2e
Total Scope 1 Emissions	3,157.0 mT of CO2e	Total Scope 1 Emissions	4,006.0 mT of CO2e
Scope 2 Emissions			
Purchased Electricity	18,337.0 mT of CO2e	Purchased Electricity	25,003.0 mT of CO2e
Purchased Heating	0.0 mT of CO2e	Purchased Heating	0.0 mT of CO2e
Purchased Cooling	0.0 mT of CO2e	Purchased Cooling	0.0 mT of CO2e
Purchased Steam	0.0 mT of CO2e	Purchased Steam	0.0 mT of CO2e
Total Scope 2 Emissions	18,337.0 mT of CO2e	Total Scope 2 Emissions	25,003.0 mT of CO2e
Scope 3 Emissions			
Commuting	2,538.0 mT of CO2e	Commuting	2,542.0 mT of CO2e
Air Travel	413.0 mT of CO2e	Air Travel	415.0 mT of CO2e
Solid Waste	0.0 mT of CO2e	Solid Waste	0.0 mT of CO2e
Total Scope 3 Emissions	2,951.0 mT of CO2e	Total Scope 3 Emissions	2,957.0 mT of CO2e
Net 2009-2010 Emissions			
Total	24,445 mT of CO2e	Net 2010-2011 Emissions	Total
Per Full-Time Enrollment	2.28 mT of CO2e	Per Full-Time Enrollment	2.96 mT of CO2e
Per 1000 Square Feet	30.68 mT of CO2e	Per 1000 Square Feet	27.87 mT of CO2e

Image 1: A two-year GHG inventory tracking indicating overall carbon emission reduction.

In absence of historic data, design energy and GHG emissions data were used to project total GHG emissions. All new buildings on campus have been designed to achieve LEED-NC certification. Some estimates indicate that as much as 600 metric tons of CO2 emissions could potentially be mitigated by maintaining, improving or expanding existing natural areas. Additionally, as a result of new building construction, the overall building area was increased by 43.95% between August 2010 and August 2011, while net GHG emissions have risen by only 30.77% during the same period. This data clearly demonstrates the benefits of energy efficient building design and construction. The data also suggest that implementation of the LEED green building rating system’s guidelines can result in significant decreases in both overall campus energy use and GHG emissions per square foot of area.

Case Study 3: College of Lake County – Grayslake Campus

The College of Lake County (CLC) used its master planning process as a platform to elevate sustainable campus operation to a new, visionary level. The 2012 Sustainable Master Plan integrated CLC’s sustainability plan, climate action plan, future building construction and operations into a cohesive set of interrelated sustainable strategies. It also outlined a vision of a carbon-neutral college campus, implementing on-site renewable energy systems such as wind and solar to achieve complete energy grid-independent operation in ten years.

CLC’s customized sustainable master plan was aimed at rectifying these vast operational differences by modernizing all existing building systems, holding new facilities to the highest performance standard and gradually strengthening on-campus renewable energy capabilities. The combined goal of these sustainable strategies was to make CLC’s main campus in Grayslake carbon-neutral (and energy-independent/grid-free) by 2021.

All future new construction is required to achieve LEED-NC Platinum certification, while all renovations will follow LEED-EBOM (Existing Building Operation and Maintenance) certification guidelines as well as the Association for the Advancement of Sustainability in Higher Education (AASHE) standards for optimal sustainable building operation.

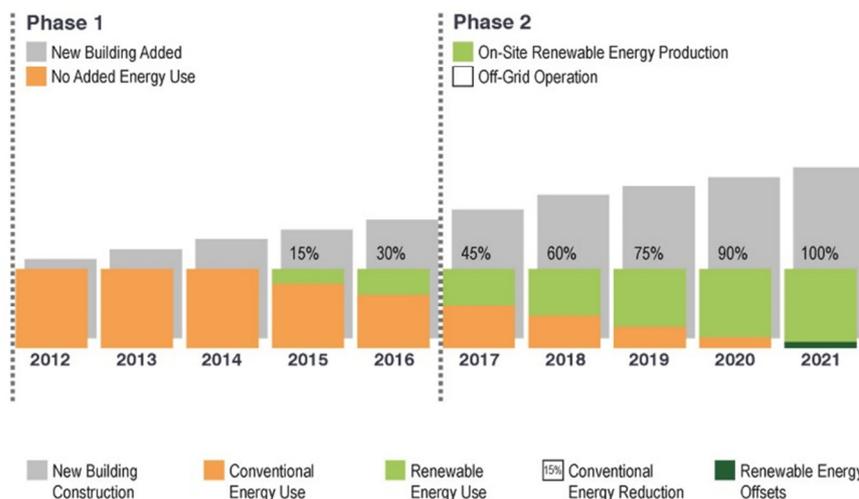


Image 2: A 10-year phased energy use reduction plan to achieve carbon neutrality and net-zero operation.

With many buildings of various ages, sizes and uses, CLC saw the sustainable master plan model as an opportunity to fully modernize and standardize its campus operations. For example, the Grayslake campus needed a complete replacement of its inefficient HVAC system in the two main buildings totaling over 206,000 square feet. The mechanical systems were so outdated that spare parts had to be machined from scratch each time a replacement was needed. At the same campus, the new Science building was being designed to achieve LEED Platinum certification, featuring 21st century, high-performance sustainable laboratories and a large roof-based solar array. This time, geothermal system was designed as



a phased, campus-wide installation, supporting multiple buildings on campus from the same field. The on-site renewable energy systems were planned to be installed as the individual building projects came on line. The Science building was designed with an integral 56 kW photovoltaic array designed to provide as much as 7% of building energy demand. The cost of the photovoltaic array was estimated at \$510,000 USD. For this building alone, overall building energy and carbon emissions were reduced by over 50 percent, due to combination of daylight harvesting, geothermal heating and cooling and photovoltaic systems.

Recognizing an increased public and industry interest in renewable energy power supply, CLC also plans to add a variety of on-site renewable energy demonstration projects on its campuses: fuel cell electrical power, solar water and air heating infrastructure, campus-wide geothermal technology, electric vehicle charging stations, commuter reduction and interior and exterior LED lighting. Most of these demonstration projects will be coupled with academic programs and training for professionals and trades seeking to acquire hands-on training of renewable energy technologies and green collar job skills.

Conclusion

Achieving carbon-neutral or net-zero operation in a college campus education environment requires appropriate funding, continuous implementation of identified carbon emission mitigation strategies, planning flexibility to address future technological developments, and time to create meaningful culture change, implement necessary building upgrades, install renewable energy systems, and plan for and secure the necessary funding.

As short-term strategies on individual projects are easier to identify and implement, mid-term and long-term strategies that involve entire campuses or communities will need to remain flexible to allow sufficient room for adaptation for future changes in the political, social, economic and natural environment. The critical element for securing success will be proper integration of carbon action plan goals and strategies into all subsequent sustainable campus planning, operations, and maintenance activities on college campuses.

While some of the GHG emission will be difficult to completely eliminate, such as those related to commuting or air travel, full carbon neutrality can be achieved through carbon offsets and/or of renewable energy credits (RECs) purchases. To achieve this, sufficient funding should be allocated for carbon offsets, parallel to budgets developed for the implementation of the entire Carbon Action Plan.

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Evaluation of the energy performance strategies in competition tenders to achieve Nearly Zero Energy Buildings: two case studies in Barcelona and Merano.

Speakers:

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Abstract: *This paper shows the experiences of two typologies of tender competition to achieve Nearly Zero Energy Buildings (nZEB) target, realized in 2013 in two cities: Barcelona (Catalunya) Spain and Merano (Bolzano) Italy. This work was carried out in the framework of AIDA Project assisting Municipalities in the Integrated Energy Design (IED) process by IREC and EURAC, as partners of the European project consortium. In particular, this paper shows the approach used during the evaluation of proposals in submission phase, from the analysis of the design solutions presented to achieve the energy target and the energy performance (demand and generation on site), as well also the score assignation (energy efficiency item). Moreover, the total score is the sum of different points from different criteria achieved (urban integration, architectural and functional quality, aesthetic, etc.). This means, that presently, the nZEB target is an important aspect, but not necessary, to reach to win the competition. In conclusion, this paper highlights the importance of the definition of tender and specification documents related to the Energy efficiency, from the early stages of the architectural design, to achieve a nZEB and integrated the IED process.*

IED process, nZEB, NZEB, submissions evaluation, energy efficiency.

1. Introduction

According to the European Directive 2010/31/EU, by 2020 all new buildings in Europe should be nZEB [1]. This ambitious target has originated, at international level, many research activities and intense scientific and political debates to clarify the Net Zero Energy Buildings - NZEB definition. Defining NZEB, developing design tools and procedures and seeking optimum design solutions for NZEB are items which were widely under discussion, as an example, the IEA Task 40 [2]. Currently, the low adoption of the EPBD at National and Regional levels and lack of definition about nZEB in many countries, has led to very low adoption of NZEB and nZEB in public and private sectors.

The AIDA Project – IEE [3] aims to accelerate the market entry of NZEB and nZEB, increasing the knowledge about these buildings among public local administrations (municipalities) and building professional and master builders (private sector). For this purpose, one objective of AIDA is to develop a method to introduce energy performance requirements into public design tenders with an IED process [4]. The IED is a multidisciplinary and collaborative process, where the work team comprises different actors

with various knowledge and experiences. This team works together to define, analyse and evaluate different solutions and possible interactions [5]. This work describes the approach used for the evaluation of the proposals submitted, from the analysis of the energy strategy of the proposals, to the score assignment.

2. Nearly and Net Zero Energy Buildings, context and definition

Due to the missing implementation of the EPBD [1] at national level, into the AIDA project, a common nZEB definition has fixed, in order to use the same method for the energy balance calculation in all the case studies involved. The starting points are been the results obtained within the international project of the IEA SHC Task 40/ECBCS Annex 52¹ “Towards Net Zero Energy Solar Buildings”, AIDA suggests to focusing at least on the results of *Net ZEB primary or Net ZEB limited* and *Net ZEB carbon* definition. Furthermore, within AIDA project, have been proposed some minimum energy performance indexes (see Table 1), in order to achieve the nZEB targets, summary on a high-energy efficient building able to produce, on site, as much energy as needed (by Renewable Energy Systems - RES).

3. Tenders

At European level, the Directive 2004/18/EC and updates, define technical, legislative and economics aspects and rule the process and the relations between public and private sector. The tender is the vehicle able to contain needs, requirements and information for bids. Contracting authorities shall treat economic operators equally and non-discriminatory and shall act in a transparent way (Directive 2004/18/EC, art.2).

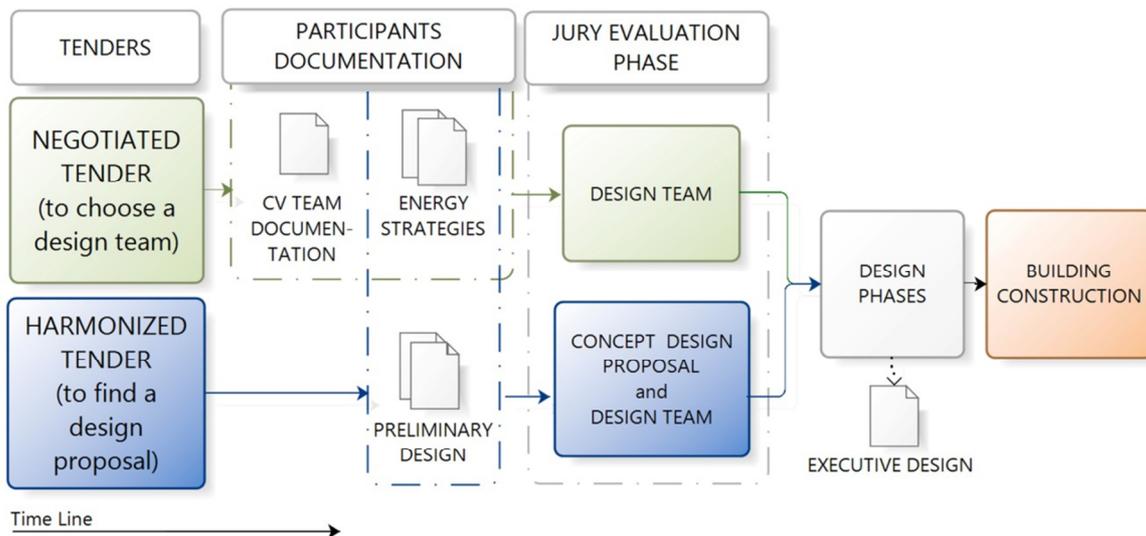


Figure 1: Tender procedures of the case studies (Source: Deliverable 3.1, IEE-AIDA²)

All European member states have implemented this Directive and its updates at national level. The building tender’s choice is closely linked to the final objectives, needs, available budget

¹ IEA, International Energy Agency (<http://task40.iea-shc.org/>)

²IEE-AIDA project: <http://www.aidaproject.eu/downloads.php>

and involved professional figures. In these case studies are been chosen two different tender procedures, but in both the nZEB target is been introduced like a necessary requirement:

New equipment in Plaça Sarrià, Barcelona: Ideas competition tender (harmonized tender) organized by BIMSA - *Barcelona d' Infraestructures Municipals, Barcelona Municipality*, to find the design team through a design competition for the new Public library, Civic Centre - District Head Office and City archive (total net floor area= 4.640 m²).

New Elementary School of Signio, Merano: Design competition tender (negotiated tender) organized by Merano Municipality to choose the design team who will design the preliminary, definitive and executive project (total gross volume 17.300 m³).

3.1. Energy specifications parts

In both tenders, is been introduced a specific part, guidelines for the energy concept, about energy specification requirements, clarification of the nZEB definition (energy target), procedure and methodology to calculate the energy balance, physical boundary of the building (generation on site), integration of the energy generation systems and weighting factors, (Deliverable 3.1, IEE-AIDA)³. Moreover, *Minimum energy performance indexes*, such as defined in IEE-AIDA project, are been introduced in this part of tenders. Being their more restrictively respect to the national/local laws the two Municipalities have decided to increase this minimum or achieve the mandatory limits (see Table 1).

Table 1: Minimum energy performance indexes

Minimum requirements	AIDA project	Merano	Barcelona
National/local energy performance classification of the building:	Standard A of National/Regional Energy Performance Certification	Standard ClimaHouse A: heating demand <30kWh/(m ² .year)	CTE Energy Certification (mandatory): level A
Primary energy- PE :	< 60 kWh/(m ² .year)		Result of PE Balance: <90 kWh/(m ² .year) *
PE % produced from RES:	At minimum the 50%	At minimum the 40%	*No specified
CO2 emissions:	< 8 kg/(m ² .year)	< 100 ⁴ kg/(m ² .year)	No specified
Others:		60% of the DHW load covered by RES; Electricity produced from RES: minimum of 20W (for each square meter covered)	Limit of Electricity demand: <75-80 kWh/(m ² .year)

*The nZEB objective will be realized by Energy balance in PE, using the conversion factors or weighting factors for different energy carriers, where energy demand includes: heating, cooling, domestic hot water - DHW, ventilation, lighting and equipment (affecting by the conversion factors to obtain the final electrical energy). The energy balance is performed on an annual basis, considering the type and efficiency of the energy systems and production of renewable energies systems (RES > 100 kWh /m².year).

³IEE-AIDA project: <http://www.aidaproject.eu/downloads.php>

⁴When the public tender of Merano was been published, AIDA's minimum energy performance criteria were underdevelopment.

3.2. Energy criteria and awarding points:

Within the tenders were introduced awarding energy performance criteria in order to assign as many points as the results achieved by the proposals. Both tenders required two energy criteria: *a)* Energy strategy to achieve the nZEB target; *b)* Composition of the design team with, at least, an Energy expert in the design team. Moreover, in Merano's tender, was required an expert able to calculate the energy balance through static and dynamic simulation tools.

New equipment in Plaça Sarrià, Barcelona: award criteria (with a maximum of 100 points), included in the Annex 6 of the Specifications document “*Global Architectonic Quality*”, were divided in 80 points for Architectonic quality, Compliance of Architectonic Program, Technical and structure consistency, Maxim costs and 20 points for Energy Efficiency (max. 15 points) and LCA- Life Cycle Assessment of materials.

New Elementary School of Signio, Merano: award criteria consisted of Design architectural proposal (maximum 30 points) and law accomplishment construction (maximum 30 points), completed on ‘Criteria to achieve nZEB target’ (max. 6 points) and ‘Experience (CV) of the Energy Adviser/Certifier (maximum 4 points).

4. Evaluation phase

4.1. The evaluation of the Energy target.

The IREC and EURAC were collaborated with BIMSA and Merano Municipality respectively, as a part of the jury, to support them to assign the score in the energy efficiency item. The criteria changed with the typology of the tender design process used. Table 2 shows the difference between the energy criteria and awarding points of the two tender procedures and the characteristics analysed and investigated within the proposals.

Table 2: Difference between the energy criteria and awarding points of the two tender procedures.

Criteria to assign points	Merano	Barcelona
Energy Efficiency target	6 points maximum	15 points maximum
<i>a) the self-sufficiency (energy)</i>	X	X
<i>b) reduce the energy demand</i>	X	X
<i>c) the buildings that incorporate intelligent systems (load control by users)</i>	X	X
<i>d) proposed a final energy target higher then ClimaHouse A (such as Gold, Nature, Passive House, LEED, etc).</i>	X	
<i>e) Sketches and drawings to supporting the energy concept.</i>	X	X
Experience of the Energy Adviser/Certifier qualification's assessment:	4 points maximum	-
<i>a) experience in energy performance building consultancy</i>	X	
<i>b) qualification of the Energy Adviser/Certifier and knowledge of energy performance simulation tools</i>	X	
Total points	10/60	15/100
Perceptual of the total score	16.66%	15%

The proposals were been composed by a written technical report and a design proposal (not necessary in Merano case). To evaluate the ‘Energy Efficiency’ criteria, and if the objective

was been achieved by the participants, the proposals were analysed from different energy performance categories, based on the analysis realized in Spain for existing building [6]. The parameters were organized in: a) *Building configuration* (Figure 2); b) *Lighting and HVAC systems* (Figure 3) and c) *Renewable energy systems generation* (Figure 4).

Within design competition (*New equipment in Plaça Sarrià, Barcelona*) there were 15 points (*that represent the 15% of total score*) for the Energy Efficiency target criteria, while in the Negotiated tender design (*New Elementary School of Signio, Merano*), there were a total of 10 points maximum available for the energy criteria (*represent the 16.66% of total score*). This means, the energy strategy of the design proposal within total score weighs 10% in Merano and 15% in Barcelona’s design competition.

5. Results

5.1. Results of the analysis of proposals.

The number of the participants was fifty-eight (58) for Barcelona and fourteen (14) for Merano. The choices reflect the background experience and knowledge of the professionals ‘experts and the construction market trend typically used in these two cities. All proposals, except a very few number, have explained their passive architecture strategies (see Figure 2) and combine them with active solutions (see Figure 3), and then some, with a RES generation (see Figure 4) probably to achieve the nZEB target.

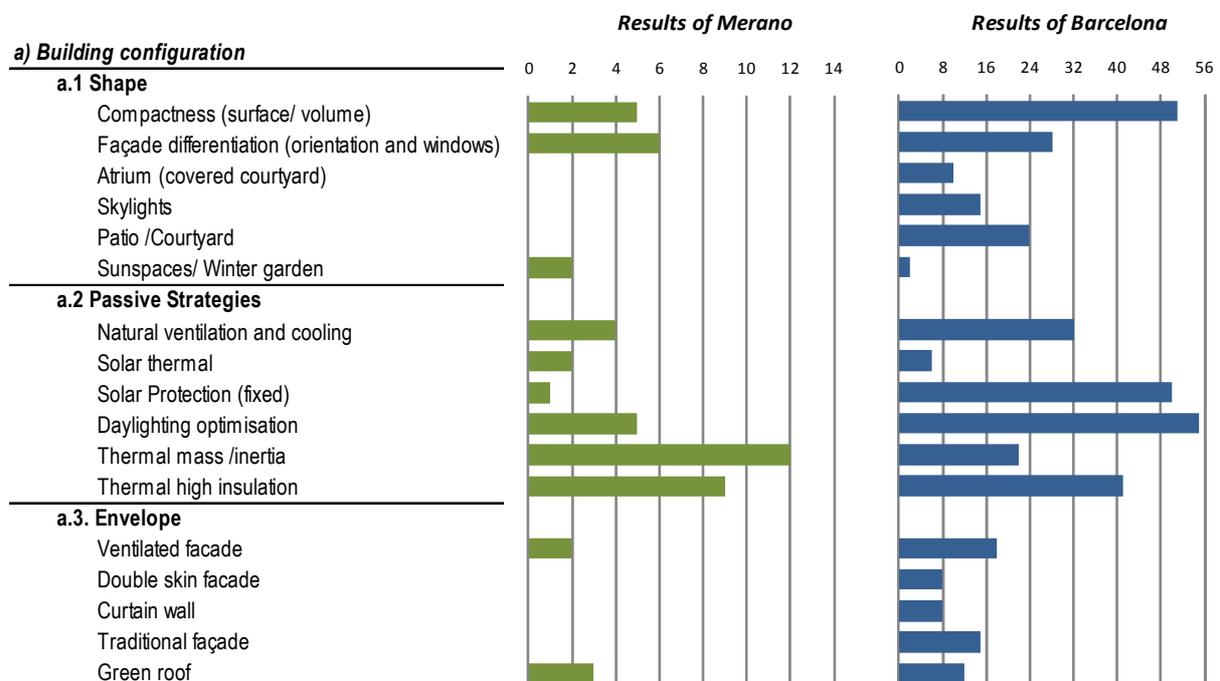


Figure 2: Analysis of Building configuration of the proposals results of Merano and Barcelona.

These results are strictly connected with the climate and the urban context. A building’s compact shape is a necessary characteristic of the new building of Barcelona’s city, development in height, due to the limit of the building construction area (plot). At the same time, the high number of façade differentiation (opaque/glass area of the façades) and thermal insulation are the most common solutions typically used in cold climate, like Merano’s one.

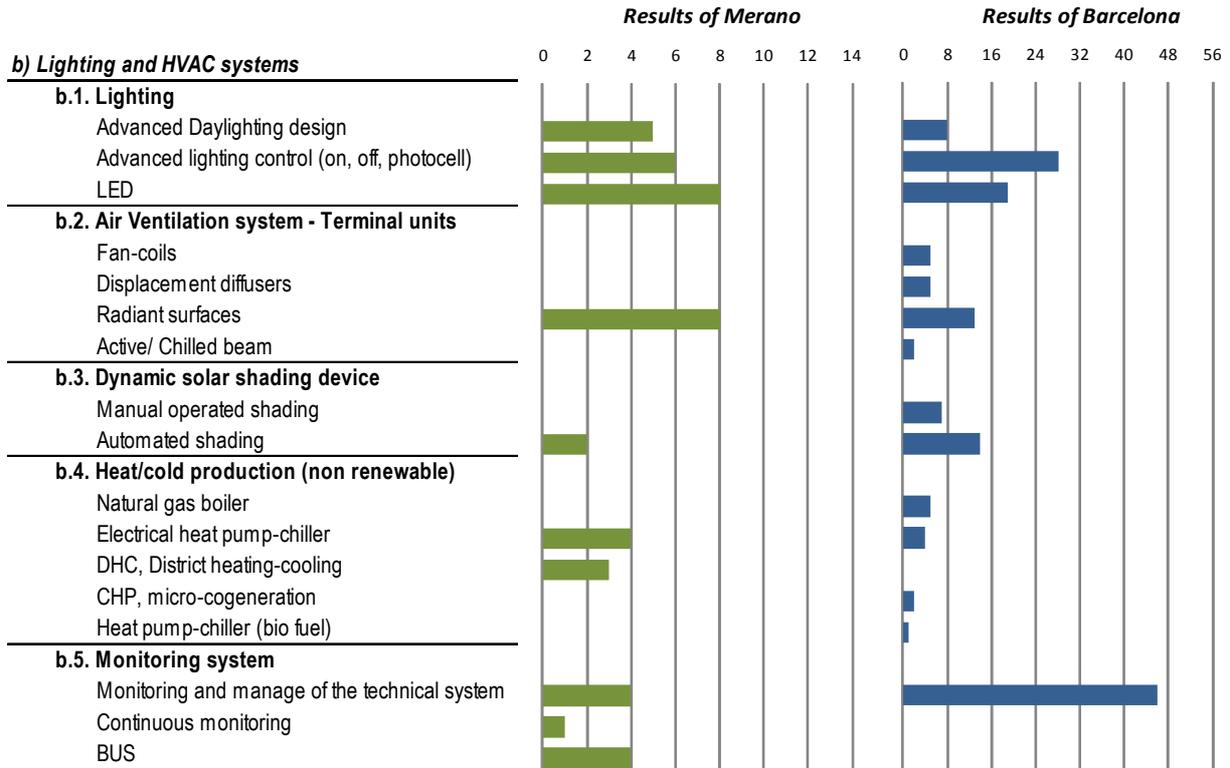


Figure 3: Analysis of Lighting and HVAC systems of the proposals results of Merano and Barcelona.

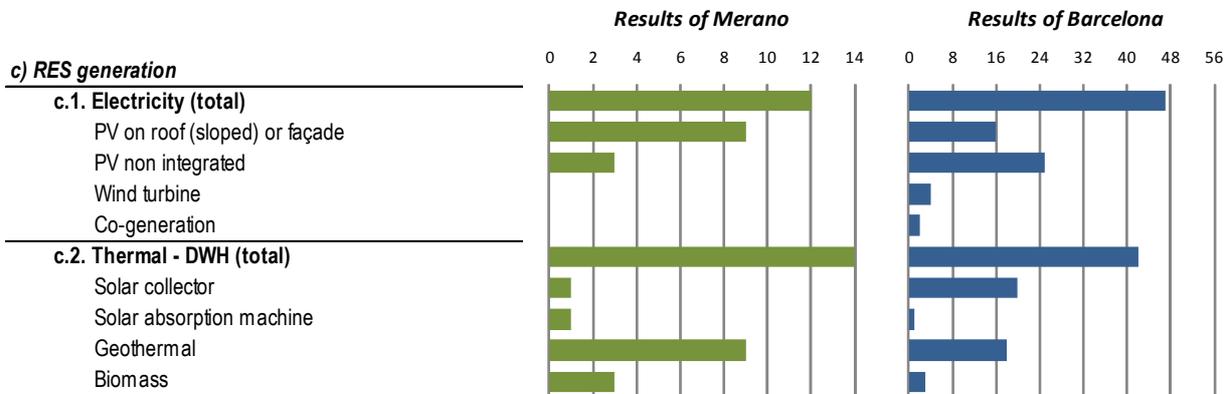


Figure 4: Analysis of RES generation of the proposals results of Merano and Barcelona.

6. Conclusions

This work suggests for future experiences a method for the analysis of the energy performance strategies of the design proposals, if the energy criteria are been introduced within the tender. This energy examination assigns as much points as the energy strategy achieves the nZEB target.

In both case studies, some misunderstandings were found. Sometimes, the participants were so determined to achieve the nZEB target, that they lost sight of the integration of the energy generation plants, like solar panels (thermal and PV ones), proposed unrealistic technical solutions for the specific urban context, or suggested contradicting solutions between technical reports and design proposals.



However, the introduction of the nZEB target requirement within public design tenders is an innovative strategy that allows increasing the energy performance knowledge and awareness in the professional expert (designers, architects, engineers and constructors) and improves the interactions between them. In addition, the complexity of the energy efficiency evaluation process of submitted proposals is highlighted, even if it is only a small part of the total score. This means that, presently, the nZEB target is an important aspect, but not necessary, to win the competition, and good proposals from this point have been discarded due to other factors (costs, architectural quality, urban context, functionality, etc.).

For the future, the energy efficiency aspects and nZEB target should drive the architectural design development, being part of architectonic language and strongly affecting the whole building configuration. In the case of the Barcelona's ideas competition the great number of design proposals submitted depict innovative approaches with similar architectural solutions. Both, Barcelona and Merano experiences, show that the energy performance-based tendering approach allow supporting this challenging achievement.

7. Acknowledgement

This work was financially supported by AIDA, an IEE- Intelligent Energy Europe Project [2]. Also, this work was possible by the collaboration of BIMSA (Barcelona) and Merano Municipality. The work of Maria Leandra González Matterson is supported by Technical Support Staff Subprogram 2011 (*Subprograma Personal Técnico de Apoyo-PTA-2011*), from Ministry of Economy and Competitiveness of Spanish Government.

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Measuring the sustainability through a life cycle perspective: the case of Sunslice, a ZEB for high density urban environment

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Abstract: *The ecological optimization of construction and disposal of nearly zero-energy buildings is the crucial step for the future. In order to confront the main challenges of the building sector, limited resources as well as the energy-efficiency and a sustainable building stock, a life cycle view is required. The life cycle perspective draws boundaries to include all phases of the building lifetime – materials, construction, use (including operating energy), replacement, end of life - and allows a representative characterization of cumulative environmental impacts over the life of the building. Coupling an LCA model in SimaPro with a detailed energy simulation model carried out with EnergyPlus, it is possible to adopt a comprehensive approach that focuses on the the impact of a set of Sunslice technical features: a dry reversible construction system with an aluminium structure, an eco-efficient envelope, passive design strategies, photovoltaic power generation.*

The case study is Sunslice, a single vertical town house for infill construction of ZEB, powered by the sun in high density urban environments, designed by the students team of the Politecnico of Turin within the international contest Solar Decathlon Europe 2014.

Keywords: *Life Cycle Assessment, Residential ZEB, Environmental sustainability, performance-based design*

1. Introduction

Life Cycle Assessment (LCA) is a recognized objective methodology used to assess potential environmental impacts of product and services during their whole life cycle, from extraction of raw materials, through production, use phase and End Of Life (EOL), with a from-cradle-to-grave approach. It represent a comprehensive methodology to evaluate and optimize a complex set of design features.

Although the general LCA methodology is well defined ((ISO 14040, and ISO 14044), its application in the building industry still suffers from a lack of sector-specific standardisation [1]. Recent standards (EN 15978 define the general framework and general calculation methods for building LCAs), methodologies or guidelines (such as EeBGuide [2] that provide consistence calculation rules and operational guidance for LCA studies conducted within the context of research projects within the Energy-Efficient Buildings European Initiative) have been developed, but actually comparison between different studies or benchmarking are still difficult to implement.

LCAs are mainly assessed in the context of building certifications, such as BREAAAM, LEED, HQE, DGNB, etc., as a best methodology for the evaluation of the environmental impact of



material and building component or the evaluation of the entire building, including the operational phase.

The paper presents the results of a detailed LCA application to Sunslice, a single vertical town house for infill construction of NZEB, powered by the sun in high density urban environments, designed by a students team of the Politecnico of Torino within the international contest Solar Decathlon Europe 2014. Sunslice is the result of an integrative design process, where the contribution of different skills within a holistic approach (planning, architecture, sociology, energy, sustainability) informed the design from the urban scale to the building one.

In this framework, LCA study represent a comprehensive methodology to evaluate and optimize the environmental impacts of a complex set of design features [4] related to the building localization, urban connectivity, construction process, materials and components selection.

2. Methodology

According to the definition of LCA, the life cycle perspective draws boundaries to include all phases of the building lifetime – materials, construction, use (including operating energy), maintenance, end of life - and allows a representative characterization of cumulative environmental impact over the life time of the building. The study aims to evaluate the environmental impact of Sunslice as a tool to efficiently inform decision-making above all related to materials and building components, a crucial point in case of energy efficient buildings and even more with plus-energy buildings [5].

During the design process, the evaluation and the optimization of the operational phase, so the energy and water related consumptions, were carried out with other tools and methodology (cfr. Par. 3.5.2) within a life cycle perspective.

Moreover, the study involves analysis in terms of the following scales [5]:

- Temporal scale, as the impacts of the buildings are now studied along its full life cycle;
- Spatial scale, as the building is taken into account as a part of the neighborhood and of the city, by analyzing the transport induced during the in-use phase, or the local energy production or storage;
- Complexity scale, as the environmental assessment is a multi-criteria analysis, taking into account energy use (non renewable, renewable, etc.), resources depletion, toxic emissions, global warming potential, water consumption.

The research presented in this paper is based on the application of LCA according to ISO standards (14040, 14044), European Standard EN 15978 and following the assumptions and conventions briefly recalled in the following paragraphs.

Considering that, in the construction sector, the level of detail of LCA studies depends on the design phase, data availability, goals and scope of the assessment, this research follows the

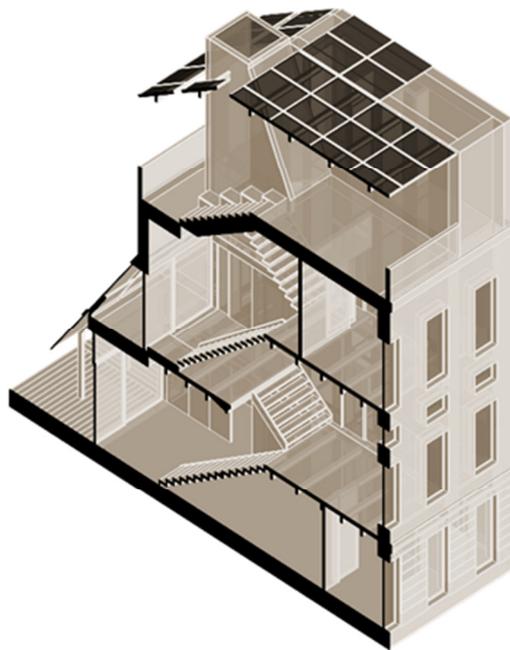
guidance on the data types and calculation rules proposed in the EeB Guide [2] for Simplified LCA (cfr. **Table 3**).

3. LCA application to Sunslice

3.1. Case study

Sunslice represents an innovative concept of residential building to take people back to a more dense city, combining the advantages of a detached-house with the advantages of the urban density.

Sunslice is a ZEB, a vertical residential building filling gaps between existing buildings, or turning brownfield areas into new living areas. The case study is located in Turin within a high density urban context. The main features are summarized in **Figure 3**.



Localization:	Turin, high density urban context
Climate zone	E, 2614 GG
Number of level	4
Net floor area	135 m ²
Condition volume	383,4 m ³
Walls area - - U value	380 m ² , 0.12 W/m ² k
Floor area - U value	72 m ² , 0.26 W/m ² k
Roof area - U value	67.9 m ² , 0.15 W/m ² k
Window Area - U value	42.1 m ² , 1.1 W/m ² k
Glazing Solar Gain (SHGC)	0,56

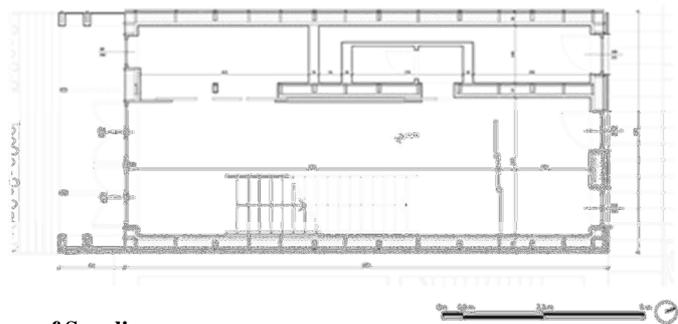


Figure 3 - Main feature of Sunslice

The construction system of Sunslice is an aluminum balloon frame, with low spacing columns and beams belonging to a curtain wall system. It is designed for the disassembling stage at the end of the building life to allow recycling and reuse of many materials.

The energy strategy comes from the integration of passive and active systems, the reduction of energy needs for lighting and appliances and the efficient control of all services and facilities. Bioclimatic studies that integrate air, water, solar heat and light, were developed in order to create a solid structure that permits to reduce thermal loads. The main source is the solar energy that generates electricity through photovoltaic panels and hot water through solar-thermal panels. On the roof it will be installed 24 SI monocrystalline modules for a total



area of 39m² (8 kWp) and 2,4 m² of solar collectors. The HVAC system integrates heating, cooling and ventilation in a single solution: it is composed by an heat pump with direct expansion internal units. Bathroom heating is composed by a low temperature radiator supplied by hot water coming from the solar water tank.

3.2. Functional unit

Since in LCAs of whole buildings, the functional unit should be defined so that the different buildings being compared provide the same services, for a similar duration, the function of the system under study can be defined by its service time, by a reference area (net/living floor area) and by occupant. So, the functional unit is one squaremeter of usable/living floor area, over one year (m²/year) or by occupant, over one year (occupant/year). We consider a building lifespan and occupancy of 50 years.

3.3. System Boundary

The study is a cradle-to-grave analysis. The system boundaries determine which unit processes are included in LCA study. The building system is broken down into process units, encompassing all the elements, materials, and components that constitute the building and are affected by flows of matter and energy during their life stages:

- Materials Manufacturing (A1-A3): removal of raw materials from earth, transportation of materials to the manufacturing locations, manufacture of finished or intermediate materials, building product fabrication, and packaging and distribution of building products.
- Construction (A4-A5): all activities relating to the project construction.
- Use and Maintenance (B1-B6): building operation including energy consumption, water usage, replacement of some building assemblies, and transport of users.
- End of Life (C1-C4): Includes energy consumed and waste produced due to building demolition and disposal of materials to landfills, and transport of waste materials.

In this study we considered also the transport of users in order to evaluate the influence of the construction site in a life cycle perspective [8]. The building is located in a high density urban environment: this means high connectivity to the community, availability of public transports, expected reduction of the use of traditional mode of transport.

3.4. Data collection

Many input data, such as quantity of materials, distance of materials manufacturers from site, operational water and energy use, etc were estimated from the design drawings and evaluations, meanwhile other data were integrated with literature references, as reported in Table 3.

The inventory datasets for material fabrication, energy production chains and transport systems were mostly extracted from the Ecoinvent 2.2 database [6] while the LCI modelling was performed using the SimaPro 7.3.3 software application.

Table 3 - Description of assumptions and sources of data following the modular description structure used into the EN 15978: The system boundary include the entire building and its foundations.

Life cycle stage		Sources of data
Product	A1 Raw Material Supply (M)	Quantities estimated from building drawings
	A2 Transport (M)	Database Ecoinvent
	A3 Manufacturing (M)	
Construction Installation	A4 Transport (O)	Real design data and literature references
	A5 Construction-installation Process (O)	Literature data Items not included: Water consumption, Transport of construction machinery to building site and workers / Waste management
Use	B1 Use (O)	Transport of users data estimated considering a real building site and literature references Other items not included in this stage
	B2 Maintenance (O)	Stage not included
	B3 Repair (O)	
	B4 Replacement (M)	We considered the replacement of interior and exterior finishing (as flooring or doors and awning) and components with an estimated lifespan under 50 years (FV panel, inverter, etc.)
	B5 Refurbishment (O)	Stage not included
	B6 Operational Energy Use (M)	Data estimated through a thermal dynamic simulation of Sunsllice
	B7 Operational Water Use (M)	Data estimated taking into account the number of occupants, design fixtures and strategies for indoor and for and outdoor uses.
End of Life	C1 De-construction Demolition (O)	Stage not included
	C2 Transport (O)	Stage not included
	C3 Waste Processing (M)	Energy for recycling data from literature
	C4 Disposal (M)	Database Ecoinvent for standard waste treatment and disposal

According to EeB Guide **¡Error! No se encuentra el origen de la referencia.** for simplified LCA - M = Mandatory, O = optional

3.5. Inventory analysis

The inventory is a list of all substances involved in the process.

3.5.1 Pre-use phase (A1-A5)

Pre-use include everything that concerns the production of materials and plants (A1-A3), their transportation to the site (A4) and the building assembly process (A5).

Materials were grouped in subassemblies taking into account the major components of structure, envelope, interior partitions, interior and exterior finishes and energy production system (FV) as reported in Table 4. As reported in many study [1], other equipments such as HVAC, electrical and plumbing equipments, were not considered in the study, since they represent minor items in the overall environmental impact.

The total weight for all the building materials and the distance from the supposed manufacturer to the building site in Turin were considered for the estimation of the impact of transportation of materials. In case of missing data, an average transport distance of 300 km was assumed [8].

We also estimated the impact of the assembly phase: this value was evaluate in terms of electrical consumption and it was assumed to be equal to 2% of the embodied energy of its construction materials as reported in the literature [7].

Table 4 - Inventory datasets for materials manufacturing (A1-A3), transport of materials (A4) and materials replacement (B5)

Sub-assemblies Description	Materials	Database Entry	Mass (kg)	Material life time (years)	Distance from site (km)
Foundation	Concrete	Concrete, normal at plant/CH U	23800	50	70
	Steel	Steel, low-alloyed, at plant/RER U	1570	50	70
Structure	Aluminium	Alluminium, production mix, at plant/RER U	8982	50	30
Wall panels	Gypsotech	Gypsum fiber board, at plant/CH U	7508	50	75
	Celenit L3	Wood wool boards, cement bonded, at plant/RER U + Rock wool, at plant/CH U	7617	50	400
	Glass wool	Glass wool mat, at plant/CH U	4914	50	380
	Celenit N	Wood wool boards, cement bonded, at plant/RER U	6280	50	400
	Mortar	base plaster, at plant / CH U	4914	50	70
	Roofing	Fiberboard	Gypsum fiber board, at plant/CH U	1178	50
	Glass wool	Glass wool mat, at plant/CH U	675	50	200
	Eco-isper	Three layered laminated board, at plant/RER U + Cork slab, at plant/RER U	1392	50	10
	Water resistant membrane	bitumen adhesive compound, cold, at plant / RER U	157	50	300*
	Wood tiles	Plywood, outdoor use, at plant/RER U	2200	10	10
	Aluminium cladding	Cladding, crossbar-pole, aluminium, at plant/RER U	25	50	300*
Plaster Parition Wall	Gypsum plaster board	Gypsum plaster board, at plant/CH U	22264	30	70
	Sub-structure	Steel, electric, un-and low-alloyed, at plant/RER U	482	50	70
Interior Doors	Wood	Door, inner, wood, at plant/RER U	338	30	165
Flooring	Ceramic tiles	ceramic tiles, at regional storage / CH U	4232	30	300*
	Ekosol N	glass wool mat, at plant / CH U	55	50	200
	Wood panel	Three layered laminated board, at plant/RER U	3542	30	10
Groundflooring	Ceramic tiles	ceramic tiles, at regional storage / CH U	2645	30	300*
	Eco-isper	Three layered laminated board, at plant/RER U + Cork slab, at plant/RER U	1282	50	10
	Glass wool	Glass wool mat, at plant/CH U	920	50	200
	Water resistant membrane	bitumen adhesive compound, cold, at plant / RER U	63	50	300*
Stairs	Wood panel	Three layered laminated board, at plant/RER U	455	30	10
	Steel	Steel, electric, un-and low-alloyed, at plant/RER U	212	30	300*
Window	Aluminium frame	Window frame, aluminium, U=1.6 W/m2K, at plant/RER U	572	50	30
	Glass	Glazing, double (2-IV), U<1.1 W/m2K, at plant/RER U	2058	50	30
	Awning	Textile,jute, at plant/IN U	18	10	30
PV System	Panels	Photovoltaic panel,single-Si, at plant/RER/I U (modified)	78m ²	30	300*
	Inverter	Inverter, 2500W, at plant/RER/I U	2p	30	300*

300* average transport distance from literature

3.5.2 Use phase (B1-B7)

Use phase include everything that concerns the energy (B6) and water consumptions (B7), building components replacement (B5) and transport of users.

Energy demand for building-related uses, including heating, cooling, ventilation, heating for DHW and lighting, was calculated with a thermal dynamic simulation carried out in Energy Plus. In relation to the expected building function, non-building-related uses are estimated in 1720 kWh/a (3 occupant) according to the Standard EN 15603:2008. The energy production from the FV and Solar Thermal system has been considered. **Figure 4** summarizes the annual energy balance considering all the uses and systems.

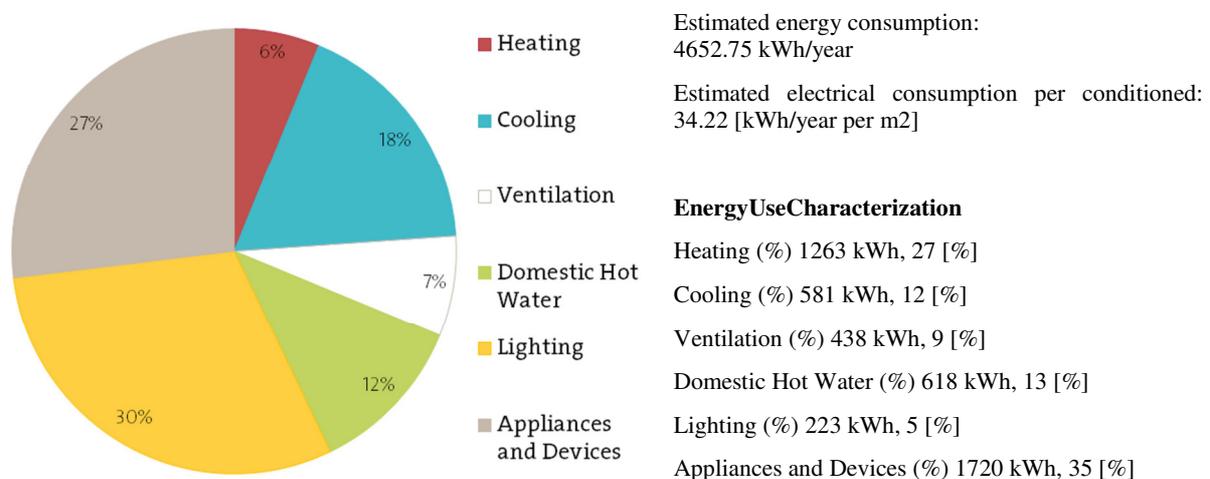


Figure 4 - Annual energy balance of Sunslice

The annual water consumption was evaluated considering all the indoor and outdoor uses, such as sanitary, domestic, cleaning, irrigation water demand.

The water demand is 155 m³/a, a lower value than the mean potable water consumption in Italian dwellings (200 m³/a) thanks to some design features, such as water-efficient, alternative water sources (rainwater) for irrigation and non potable water application, high efficiency irrigation system.

The number of occupant, the types of services available close to the building (such as shops, primary and secondary schools, cultural facilities, etc.) and transportation modes available have been considered to quantify the potential trips generated by a building, located in a central area near many basic services. Using the tool developed by Effinergie to evaluate the potential of eco-mobility (www.effinergie-ecomobilite.fr/), we estimate these mean quantities par day: 14 personne.km by car, 7 personne.km by tram, 2 personne.km by bike.

3.5.1 End of life phase (C1-C4)

The end of life of building products is one of the most difficult part of an LCA, as it requires to forecast what would happen in the future for dismantling and recycling (or disposing) of

construction and demolition waste (C&DW). In order to take account of the recycling potential of building materials, the end of life scenario adopted the avoided products approach, considering the recycling potential of the aluminium structure and plasterboard. According to this approach their EOL chain are modelled including the energy necessary for recycle them in the production of new materials. For other products and sub-assemblies, a disposal scenario to landfill was considered.

3.6. Results and discussion

To analyse inventory results, some energy and environmental indicators based on accepted methods are adopted (indicators defined in the NF P01-010 standard):

- Non renewable energy (NRE) Renewable energy (RE), as energetical indicators derived from the “cumulative energy demand” method;
- Global warming potential (GWP 100) as an indicator of greenhouse emissions with a time horizon of 100 years, according to the IPCC 2007 GWP 100a;
- Water Depletion (WD), as defined in the BEEv4 method.

Table 5 summarizes the environmental indicators divided for relevant life cycle stage. In order to enhance comparability with other studies, the EOL is assessed and presented, but always kept separate with an option for exclusion. Thanks to the extra energy production from renewable surces during the operational phase, the use stage contribute to reduce the overall environmental impact during the Sunslice life cycle in terms of RE, NRE e GWP100. So that, the influence of materials manufacturing and transport of users grows considerably (respectively 37-89% and 5-25% depending on the indicator considered), meanwhile transportation of materials and building construction process play a minor role (respectively 0,1-0,8% and 1,2-5%).

Table 5 - Lfe cycle energy and environmental impact indicators

Indicator	Unit	Materials Manufacturing (A1-A3)	Transport of materials (A4)	Construction (A5)	Use	Transport of users	End of life	Life Cycle
RE	MJ	677899,9	469,9	9370,9	-31268,2	40341,0	-202623,4	494190,1
	MJ/m ² a	100,4	0,1	1,4	-4,6	6,0	-30,0	73,2
NRE	MJ	2415775,5	33303,6	214162,8	-781853,4	838915,4	-230751,7	2489552,2
	MJ/m ² a	357,9	4,9	31,7	-115,8	124,3	-34,2	368,8
WD	Litre	5165537,2	15837,6	186546,8	8116887,8	536525,9	-1198594,2	12822741,1
	l/m ² a	765,3	2,3	27,6	1202,5	79,5	-177,6	1899,7
GWP 100	kg CO ₂ eq	126680,1	1986,6	1765,3	-4411,0	45081,9	-22806,2	148296,8
	kgCO ₂ eq/m ² a	18,8	0,3	0,3	-0,7	6,7	-3,4	22,0

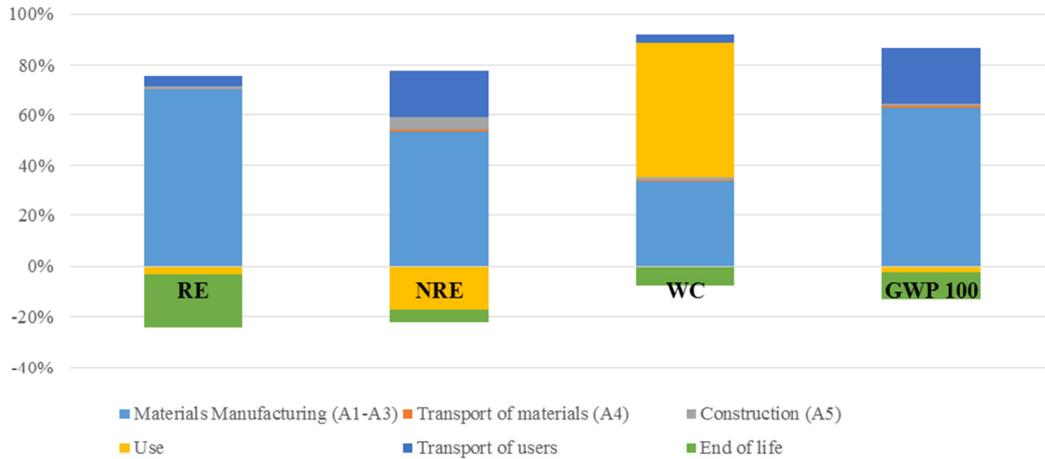


Figure 5 - Contribution analysis of life cycle stage

A contribution analysis was conducted to examine the role of the different sub-assemblies highlighted in Table 4 considering the pre-use phase and EOL scenario. As illustrated in **Figure 6**, aluminium structure is the most important contributor to all the indicators (33%-58%), followed by wall panels (13%-17,5%) and building envelope in general. On the other hand, it's important to note that these sub-assemblies have the greater recycling potential, corresponding to a positive influence in the end of life scenario and to a significant reduction in the overall life cycle impacts (cfr. **Figure 5** and Table 5).

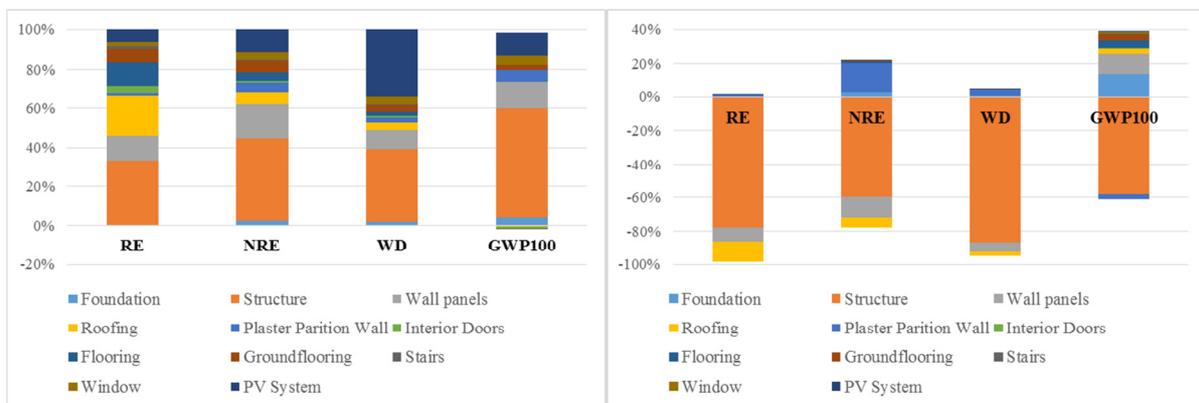


Figure 6 - Contribution analysis of defined sub-assembly in the manufacturing stage (on the left) and EOL (on the right)

4. Conclusion

The life cycle perspective was useful to orient and inform the Sunslace design process, from the building localization, to the construction technology evaluation, materials selection, etc, all aspects that were analyzed with followings simplified LCA models. In this sense, comparative LCA models are effective tools for the environmental optimization within a performance-based design framework.

In general, the study clearly highlights the significance of the pre-use phase in ZEB, even more in energy plus buildings. It becomes important to use a LCA approach to efficiently inform decision-making throughout the building design process leading to identify building



environmental “hot spot” in order to minimize the overall impact of the final building: field of study could be materials optimization, eco efficient EOL management, as a consequence of a correct choice of materials, construction system and recycling process or maintenance of building components. Another important aspect to be considered is the building localization in relation to the occupant needs, modes of transport available and the accessibility of basic services to control the impact of transports during the use phase.

The study confirms that to meet the goal of environmental sustainability it's fundamental to follow an holistic approach to the design integrating the knowledge of different disciplines, from architecture to engineering, urbanism, sociology within a scientific and objective tool.

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Cost Optimal and Zero Energy levels in the renovation of residential buildings – Rainha Dona Leonor case study (Best Papers SB13)

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***Abstract:** Improving energy efficiency in existing buildings is a great challenge. These buildings have their own limitations related with their design, location and function. To study the possibilities of cost-effectively improve the thermal performance of these buildings and increase the chances of reaching the nearly zero energy (nZEB) target, one building of Rainha Dona Leonor neighbourhood has been analysed. The purpose of the study was to analyse the robustness of the cost optimal methodology when renovating towards nZEB targets. With this work it was possible to understand that the most cost effective package of renovation measures to achieve cost optimal levels and to achieve the nZEB target are very similar and these results do not suffer major changes when variations on the energy prices, discount rates or photovoltaic (PV) costs are considered. However, these changes make the use of PV more cost-effective and nZEB levels become, sometimes, also cost optimal levels.*

Cost optimal, nZEB, energy efficiency, sensitivity analysis

Introduction

In Europe the buildings sector is responsible for 40% of total energy consumption and 36% of CO₂ emissions [1]. In Portugal the building sector is the third largest consumer [2], therefore it is important to improve the energy performance of buildings in order to reduce the greenhouse gas emissions (GHG) [3].

In a step further to fight against the increase of GHG, EU released a recast of the Energy Performance of Buildings Directive (EPBD) [4] introducing the nZEB concept and establishing its mandatory implementation for new buildings after the end of 2020 [1]. EPBD recast further requires that energy performance levels for buildings and building elements are cost-effective during their life cycle and established a methodology for its calculation [4].

The nZEB target in buildings usually involves high levels of insulation, very efficient windows, good levels of air tightness and controlled ventilation [1]. Regarding the energy sources, EPBD demands that most of the already very low energy needs in these buildings are to be satisfied by renewable energy sources harvested on-site [1]. Existing buildings face several barriers when it comes to refurbishment and even more when the target is nZEB, getting even more difficult when the building is part of social housing [5] where buildings are usually rented to poor people and so, the rents should be kept at reasonable levels [5].

Methodology

The present article describes the life cycle cost assessment of different renovation scenarios for a typical social housing neighbourhood recently renovated [6]. In this work, the cost optimal levels were identified and it was analysed in what way it is possible to reach a building with zero non-renewable energy use. The cost optimal calculations were based on the cost optimal methodology proposed by the European Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 [7], [8]. Different scenarios were tested, involving improvements in the building envelope and the replacement of the building integrated technical systems for heating, cooling and DHW (BITS). A life cycle of thirty years was considered, taking into account BITS replacement after their lifetime according to EN 15459 and considering its residual value in the end of the period. A discount rate of 6% was used. The different packages of renovation measures considered are presented in Table 1.

Table 6 Summary of the different renovation measures considered in the study

BITS (Heating/cooling/DHW)	Scenario	Walls	Roof	Window	Glass
HVAC + electric heater with storage tank + Solar panels (except B)	B	EPS 6cm	XPS 5cm	wood	single
	S1	EPS 8cm	XPS 8cm	PVC	double
	S2	EPS 10cm	XPS 10cm	PVC	double
	S3	EPS 12cm	XPS 12cm	PVC	double
Gas boiler	S4	EPS 5cm	XPS 5cm	wood	single
	S5	EPS 8cm	XPS 10cm	PVC	double
	S6	EPS 12cm	XPS 12cm	PVC	double
Heat pump	S7	EPS 6cm	XPS 5cm	wood	single
	S8	EPS 8cm	XPS 8cm	PVC	double
	S9	EPS 12cm	XPS 12cm	PVC	double
	S10	EPS 8cm	XPS 8cm	PVC	double
Biomass boiler + HVAC	S11	EPS 6cm	XPS 5cm	wood	single
	S12	EPS 8cm	XPS 10cm	PVC	double
	S13	EPS 12cm	XPS 12cm	PVC	double

For each BITS there are different combinations of measures to improve the building envelope that together form different renovation scenarios (Sn). The reference renovation scenario (B) is the adopted renovation solution for the case study. The investment and maintenance costs were calculated with the Cype® software for generation of construction prices (<http://www.geradordeprecos.info/>). The energy needs were calculated according to the Portuguese regulation for the residential buildings thermal performance [9] in accordance with ISO – 13790 and primary energy was calculated considering conversion factors of 2.5kWh_{PE} per kWh for electricity and 1kWh_{PE} per kWh for gas. The indoor comfort temperatures considered were 20°C for winter and 25° for summer. The energy costs were based on the Portuguese energy costs and it has been considered the EU scenario [8] for the estimation of the energy prices in the near future. To assess the robustness of the methodology used and the confidence on the results achieved, some sensitivity analysis were carried out regarding the evolution of energy prices, discount rates and PV prices.

Case-study

The case study is a building from the social housing Rainha Dona Leonor neighbourhood. It was built in the fifties of the twentieth century and it is located in Porto, northwest of Portugal. The building under analysis is a semi-detached house. The envelope did not have any insulation and there were wooden window frames with single glazing and external plastic shutters. The system for DHW production was an electric heater with storage tank and there were no heating and cooling systems apart from portable electric heaters or fan coils.

The renovation project aimed at increasing indoor living areas, improving thermal insulation and replacing BITS. Figure 1 shows the building before and after the renovation process. The initial heating needs of this building were 119,7kWh/m².a, the cooling needs 6,5kWh/m².a and DHW needs 37,1 kWh/m².a.



Figure 7 Building before and after renovation on Rainha Dona Leonor neighbourhood

Renovation process

The reference renovation scenario corresponds to the renovation solution really implemented in the building, including ETICS with a 6 cm thick layer of EPS on the exterior walls, XPS with 5 cm on the roof, wooden frame windows with double glazing and a new electrical water heater with storage tank combined with solar panels for DHW. For heating and cooling, a HVAC system with multi-splits was considered. Table 2 shows the energy needs, the primary energy use and carbon emissions for the initial situation of the building (before renovation) and considering the above mentioned renovation scenario (after renovation).

Table 2 Summary of the energy needs and carbon emissions before and after renovation

	Heating needs (kWh/m ² .a)	Cooling needs (kWh/m ² .a)	DHW (kWh/m ² .a)	Primary energy use (kWh/m ² .a)	Emissions (Ton eq CO ₂)
Before renovation	119,7	6,5	37,1	413,7	18,9
After renovation (Scenario - B)	68,5	7,9	27,1	127,2	5,8

Taking this renovation scenario as reference and analysing the cost optimal solution for the alternative renovation scenarios from Table 1, the results are presented in figure 2.

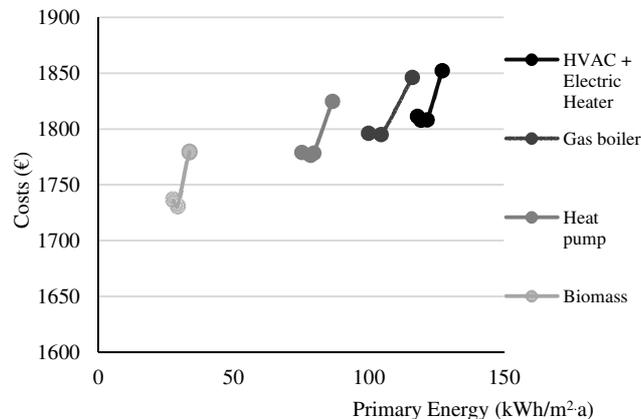


Figure 8 Global costs for each one of the alternative scenarios regarding primary energy use

This figure shows a graphical result with the primary energy for each scenario and its global cost. Each group of points corresponds to different BITS and the lower point of each group is the cost optimal solution for that equipment. The cost optimal renovation scenarios for each BITS are (according to Table 1): S2 for HVAC with electric heater and solar panels for DHW preparation; S5 for the gas boiler; S9 for the heat pump; and S12 for biomass boiler.

Among all the renovation scenarios analysed, the cost optimal solution is S12 (the global lowest point in Figure 2) corresponding to the use of a biomass boiler for heating the living room and preparation of DHW and a HVAC system in the rooms. This solution leads to primary energy needs of 29.3 kWh/m².a, which corresponds to 30% of the primary energy needs of the reference scenario (B). Table 3 shows the U-values for the reference scenario, for the cost-optimal solution and the Portuguese thermal regulation reference values.

Table 3 U-values for the base solution, for the cost-optimal solution and the Portuguese thermal regulation reference values

Element	U – Value (W/m ² .°C)		
	Reference scenario B	Cost optimal scenario	Thermal regulation reference values
Exterior walls	0,45/0,48*	0,37/0,39*	0,50
Roof	0,34	0,34	0,40
Windows	3,90	2,40	2,90

* The 1st value is for the first floor and the 2nd for the second floor

Renovation process towards net zero energy level

To achieve the nZEB level, beyond the cost optimal level, it is necessary to harvest renewable energy on site. In this case-study, the nZEB level was achieved considering the contribution of PV panels. Figures 3 and 4 show the results obtained, in terms of energy and global costs, with the contributions of PV panels for each one of the analysed renovation scenarios. Each figure represents the results for each one of the combinations taking into account heating, cooling and DWH preparation, with and without PV panels. Each different marker on figures represents one scenario, with and without PV panels to reach zero balance between the use of primary non-renewable energy and the on-site generation of energy from renewable sources.

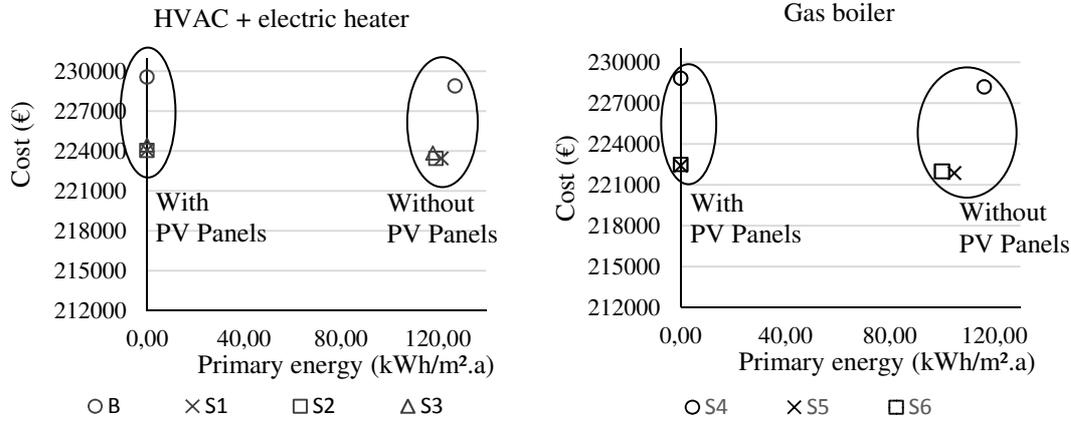


Figure 3 Results with photovoltaic panels for HVAC + Electric heater and for the Gas boiler

Analysing the figures it is possible to observe that most scenarios do not have significant changes with the addition of the PV panels in terms of the lowest global costs. In Figure 3, the cost optimal solution for HVAC with the electric heater for DHW preparation corresponds to the square marker (the lowest point) and it corresponds to scenario 2 (S2). For the gas boiler the cost optimal solution is the X marker and it corresponds to scenario 5 (S5).

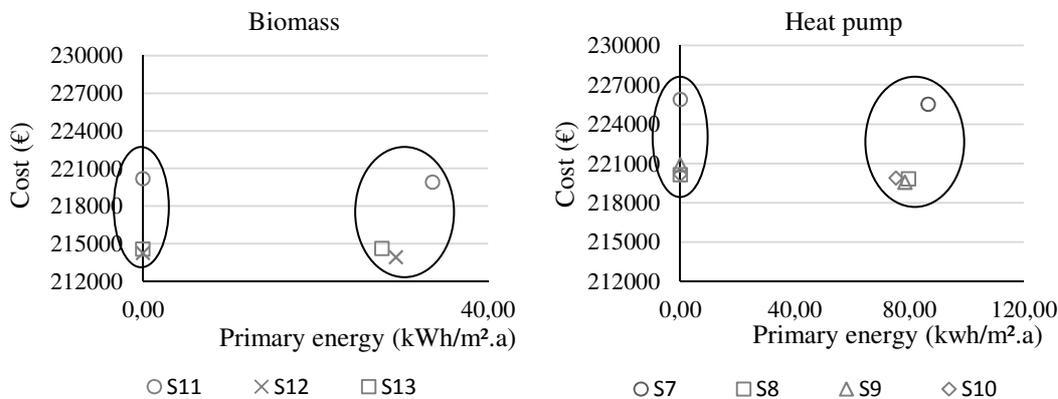


Figure 4 Results with photovoltaic panels and heat pump and biomass boiler

The inclusion of the PV panels to reach nZEB level does not change the cost optimal solution for these two BITS. It remains the S2 and the S5 solutions respectively. Figure 4 shows the same situation for the case of having a biomass boiler or a heat pump as BITS in the renovation process. The cost optimal solutions for each one of these BITS are the scenario 12 (S12) and the scenario 9 (S9) respectively. The addition of PV panels does not change also the cost optimal solutions in each case that remain the S12 and S9 scenarios.

Sensitivity analysis

To assess the robustness of the results regarding future changes in the energy prices, discount rates and PV prices, some sensitivity analyzes were performed. For the energy prices it was considered a growth of 5% per year and for the discount rates 3%. For the photovoltaic prices, instead of 3.000 €/kWp, it was used 2.500€/kWp and 3.500 €/kWp.

Regarding the changes in the energy prices, the results show that for the cases of using HVAC with the electric heater and for the case of using biomass boiler, there are no changes in the cost optimal scenarios. For the case of using gas boiler and for the case of using heat pump without the contribution of the photovoltaic panels, the cost optimal scenarios correspond to the ones with higher levels of insulation in the building envelope.

Changes in the discount rates in the cases of using gas boiler or heat pump also demand higher levels of insulation, when compared to the base solutions in order to reach the cost-optimal solutions.

Regarding the PV systems, considering a price of 2.500€/kWp, the cost optimal solutions for the analysed BITS do not change. When the price rises to 3.500€/kWp, the less efficient equipment requires a better envelope solution. Table 4 summarises these results.

Table 4 Results of the sensitive analysis showing the cost-optimal solutions for each BITS

BITS	Base	Energy evol. 5%	Discount rate 3%	PV 2500€/kWp	PV 3500€/kWp
HVAC + gas heater	S2	S2	S2	S2	S2
HVAC + gas heater + PV	S2	S2	S2	S2	S2
Gas boiler	S5	S6	S6	S5	S5
Gas boiler + PV	S5	S5	S6	S5	S6
Heat pump	S9	S10	S10	S9	S9
Heat pump + PV	S9	S9	S10	S9	S9
Biomass boiler	S12	S12	S12	S12	S12
Biomass boiler + PV	S12	S12	S12	S12	S12

Figure 5 shows the global costs for each one of the cost optimal scenarios, in each BITS with and without photovoltaic contribution, for each sensitivity analysis. Each bar is an alternative scenario in the sensitivity analysis and each group of bars corresponds to one of the BITS.

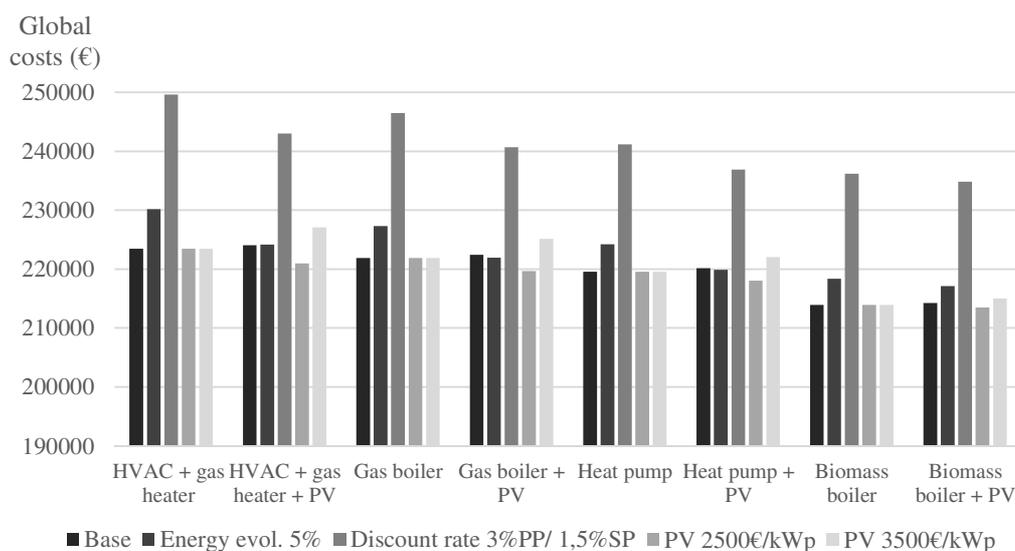


Figure 5 Global costs for the sensitive analysis in each system without and with photovoltaic panels



As shown in figure 5, for higher energy prices, lower discount rates and lower PV costs, the solutions which consider the PV systems for the energy generation are more cost-effective than the same solutions with energy supplied by the power grid.

Conclusions

In this paper, a renovation process of a residential building from a social housing neighbourhood built in the fifties in Porto was presented to evaluate how cost optimal levels relate with nZEB targets. Some clues on how the Portuguese building stock can cost-effectively move towards nZEB are pointed out.

The cost optimal calculations show that the lowest global costs are achieved with the combination of a small biomass boiler for DHW and heating and a HVAC for heating and cooling. For the building envelope, values below the current reference values of Portuguese regulation are cost-effective. The combination of a building envelope with good energy performance with simple, but efficient, BITS with low maintenance costs, proved to be a winning strategy either for the cost optimal target as well as to be combined with the use of PV panels for the zero non-renewable primary energy goal.

Sensitivity analyses on the variation of energy prices, discount rates and PV prices, allowed concluding that, for some cases, the energy performance of the building envelope has to be improved for future perspectives of higher energy prices or lower discount rates. However, this improvement in the building envelope is never very significant and doesn't happen with the use of the most efficient equipments.

The sensitive analysis further allowed concluding that lower PV costs, lower discount rates and higher energy prices, lead the solutions with photovoltaic contribution to present lower global costs than the same solutions without that contribution. This means that for these scenarios the electric energy produced by the PV panels is cheaper than the energy purchased from the grid and nZEB scenarios become cost optimal as well.

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Session 102:

What key elements will determine construction materials' future?

Chairperson:

Miguel Mitre, Emilio

GBCe, Madrid, Spain



Assessment of carbon footprint of laminated veneer lumber elements in a six story housing – comparison to a steel and concrete solution

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Abstract: *Many actions have been taken to decrease the operational energy use in buildings. However, with higher energy efficiency standards, the focus is increasingly shifting to energy demand for the production of building materials and the related greenhouse gas emissions. This study is assessing a six story housing complex that was constructed in Gothenburg, Sweden in 2012 with a structure made of laminated veneer lumber floor elements and glue laminated beams and columns.*

Building with wood in Norway is generally regarded as a carbon efficient solution, but the impact of additional materials such as glue and insulation that can influence the overall results is of interest. Life cycle assessment is used as a tool to calculate the carbon footprint in the production of the main building materials of the structure. The goal of the assessment is to compare the wood structure as built with an equivalent steel and concrete structure.

Carbon footprint, laminated veneer lumber elements, six story house

Introduction

The Norwegian research project KlimaTre aims to increase knowledge on the life cycle environmental impacts of different value chains of Norwegian timber. The project is divided into three sub projects focusing on different parts of the value chain, KlimaVerdi, KlimaModell and FramTre. The goal of FramTre is to increase knowledge on the life cycle environmental impacts of timber construction and this study is performed as a part of the activities in FramTre. Moelven Limtre are involved in the research project KlimaTre and have provided the case study of the six story residential building in Gothenburg, Sweden called Trä8. In the Research project MIKADO, Sintef Building and infrastructure prepared environmental declarations (EPDs) for 10 solid wood products, including the glued laminated timber EPD that is used in this assessment (Wærp et al. 2009).

Traditionally energy use in the operating phase has been the largest contributing factor of the entire life cycle energy use, but the importance of the materials is increasing when common practice is moving towards more energy efficient buildings. The material impact is especially important in the short time perspective with the climate mitigation goals like EU 20-20-20, since the material production impacts will occur in the nearest future. By looking explicitly at emissions connected to the bearing systems and possible alternatives one gains better



knowledge on how these emissions can be reduced. Gustavsson et al., (2006) concluded that the life cycle GHG emissions from a timber framed building are low compared to a concrete framed building. The study concluded that the climate benefits are largest when the biomass residues from the production of the wood building materials were fully used in the energy supply system. Petersen & Solberg (2002) concluded in their most likely scenario that there can be substantial emission reduction from using glue laminated beams instead of steel at Gardermoen airport.

The increased focus of climate change mitigation through low carbon footprint of building materials often leads to methodological questions and disputes. A recent attempt to reduce this dispute is the development of European standards for CEN/TC 350, where EN 15804 and EN15978 are of special interest. This report takes the building Askim Torg hus A (Trä8) as a test case for these standards. This analysis does not analyze the full life cycle emissions, but only the production stage of the different types of building materials.

The building Trä8

The building is located near Gothenburg in Sweden and was built by Moelven Töreboda. General information of the building is given in Table 1.

Table 1: Facts about the building Askims Torg with Trä8

Building owner	Hökerum bygg AB
Area	5000 m ² BTA, two blocks with common parking and 60 flats
Architecture	Aritekthuset I Jönköping AB
Entrepreneur	Moelven Töreboda
Contract	Property developer, Hökerum bygg AB
Structure	Parking basement in concrete, beams and columns in gluelam, LVL elements for floors. Elevator shaft in concrete with steel for support.

An existing building of two floors was torn down and the new building was built on top of old decking above basement. The wood frame system was chosen because of its low weight. The frame system called Trä8 consists of columns and beams in gluelaminated timber (gluelam) and can have a span up to 8 times 8 meter. The span in this project is up to 7 m. Timber work elements consist of laminated veneer lumber (LVL). These are delivered pre-manufactured. The elevator shaft and the stairway shafts are made in reinforced concrete. In one façade the beam and column system is made of steel and there are diagonal struts of steel in the framework in three corners. The bearing system is shown in Figure 1.



Figure 1: Gluelam beams and posts in the building (Photo: Per Skogstad)

Methodology

The goal of this assessment is to find the carbon footprint of the bearing system in a six story building built with glue laminated wood frame and to compare it to an equivalent steel and concrete solution. The goal is further to analyze the largest impacts and identify possible means of reduction of green house gas emissions. The assessment has been conducted on three levels, which are building level, element level and product level. The building level shows the total impact of the equivalent structures and the overall difference of the building alternatives. At the element level, the timber work elements of laminated veneer lumber are compared with pre-casted concrete elements of hollow core slab type where they both have additional materials required for the same functional equivalent. On both the building level and element level, the as built version have been assessed both with generic and specific data, while for the concrete and steel have only generic. At the product level, the different sources of data on laminated veneer lumber (LVL) and gluelam have been assessed for contribution analysis along with the generic data for concrete. SimaPro version 7.3.3 (SimaPro 2012) is used for calculating the emissions and the carbon footprint is calculated with IPCC Global warming potential, measured in kg CO₂-eq. with a 100-year scenario (IPCC 2007).

A1-3 PRODUCT STAGE			A4-5 CONSTRUCTION		B1-7 USE STAGE					C1-4 END OF LIFE			
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4
Raw material supply	Transport	Manufacturing	Transport	Construction installation process	Use	Maintenance	Repair	Replacement	Refurbishment	De-construction demolition	Transport	Waste processing	Disposal

Figure 2: This case study includes phases A1-3, the product phase based on the standard EN-ISO-15978.

The analysis is based upon the standards EN15804:2012 and EN 15978:2012 for environmental assessment of buildings. This assessment only includes the products stage,

which consists of raw material supply (A1), transport of raw materials to manufacturing (A2) and manufacturing (A3). See Figure 2 for the life cycle phases of a building from EN15978. The balconies are not included in the analysis.

The parts of the building included in both alternatives foundation are the elevator shaft, structural beams and posts and floors. The inventory, both quantities and environmental data use for the building as built is give in the Tables 2-5 below and the concrete and steel alternative in Tables 6-7.

Table 2: Material use for foundation and elevator shaft

Input	Use in building		LCI background	
	Amount	Unit	Generic	Specific
Concrete	928	m ³	Ecoinvent -	
Reinforcement steel	92 834	kg	Ecoinvent -	

Table 3: Beams and columns inventory for the building as built

Input	Use in building		LCI background	
	Amount	Unit	Generic	Specific
Glue laminated timber	128	m ³	Ecoinvent	Wærp 2009
Supporting steel	10288	kg	Ecoinvent -	
Steel fittings for wood	5055	kg	Ecoinvent -	

Table 4: Flooring elements of laminated veneer lumber type RA100 of 14 m².

Input	Use in building		LCI background	
	Amount	Unit	Generic	Specific
Laminated veneer lumber	668	kg	USLCI	Zimmer & Kairi 2001
Glass wool insulation board	75	kg	Ecoinvent -	
Glue	0,919	kg	Ecoinvent -	

Table 5: Additional materials to the looring elements of laminated veneer lumber per m².

Input	Use in building		LCI background	
	Amount	Unit	Generic	Specific
Fermacell board	28	kg	Ecoinvent -	
Stone wool insulation board, 25mm	4	kg	Ecoinvent -	
Acoustic profile	1.26	kg	Ecoinvent -	
Gypsum board, standard	9	kg	Ecoinvent -	
Gypsum board, fire	12.7	kg	Ecoinvent -	

An alternative building has been modeled to represent the typical practice for this kind of building. This is a bearing system of steel beams and posts with concrete hollow elements. The concrete hollow elements do not need the additional boards above and under, but have to be 320 mm thick to fulfill the acoustic requirements of Swedish class C. The length of the elements is in this alternative design made with the same as the wood structure. In addition to concrete and steel, 40 mm of screed material and vapor barrier is needed for the concrete floor.

Table 6: Steel beams and columns of building

Input	Use in building		LCI background
	Amount	Unit	Source
Steel	115573	kg	Ecoinvent -

Table 7: Flooring elements of hollow concrete per m².

Input	Use in building		LCI background
	Amount	Unit	Source
Vapour barrier, 0.2 mm	0.185	kg	Ecoinvent -
Screed material, 40 mm	72	kg	Ecoinvent -
Concrete hollow element HD320	413	kg	Ecoinvent -

Specific data on the glue laminated beams is based on an environmental product declaration on glue laminated beams from Moelven Limtre conducted by SINTEF Building and Infrastructure (Wærp 2009). The generic data is all gathered from processes in Ecoinvent version 2.2 (Ecoinvent 2012) except the life cycle inventory of the LVL that was missing in Ecoinvent and therefore taken from the American database USLCI (2012). Specific data is also used for the LVL named Kerto by Finnish manufacturer (Zimmer & Kairi 2002).

Results

The results at building level shown in Figure 3 indicate that the carbon footprint of the building as built with generic or specific data have almost the same results. The concrete and steel alternative has an impact that is about 35% higher than the as built wooden building. The building part that has the largest contribution is foundation in all the scenarios and it is also foundation has the same impact on all the scenarios.

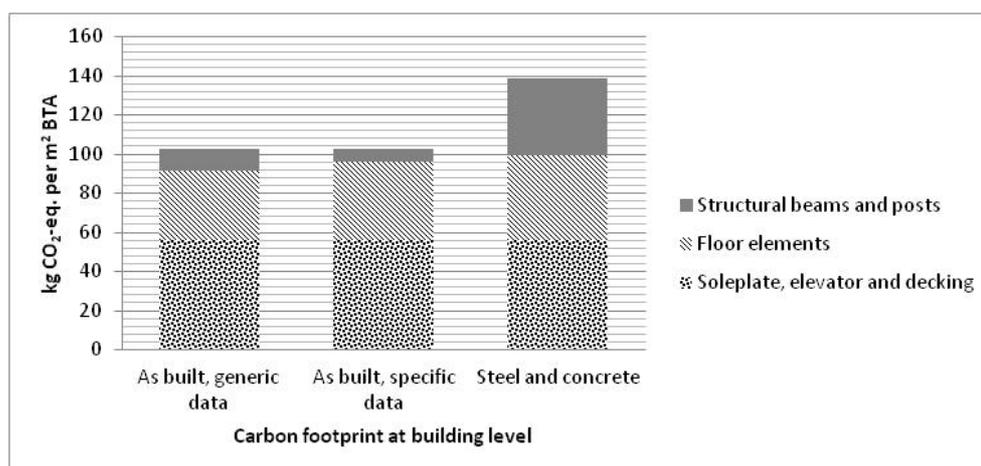


Figure 3: Carbon footprint at building level

Results shown in Figure 4 of comparing the flooring elements shows that the as built generic have the lowest impact and the as built with specific data have about 12% higher which is due to higher contribution of the LVL. For the LVL-element, the material needed additional to the element in order to fulfill the functional equivalent to the concrete have about the same contribution as the element itself. The concrete flooring elements have about 25% higher impacts than the generic as built scenario and it is the concrete that contributes most.

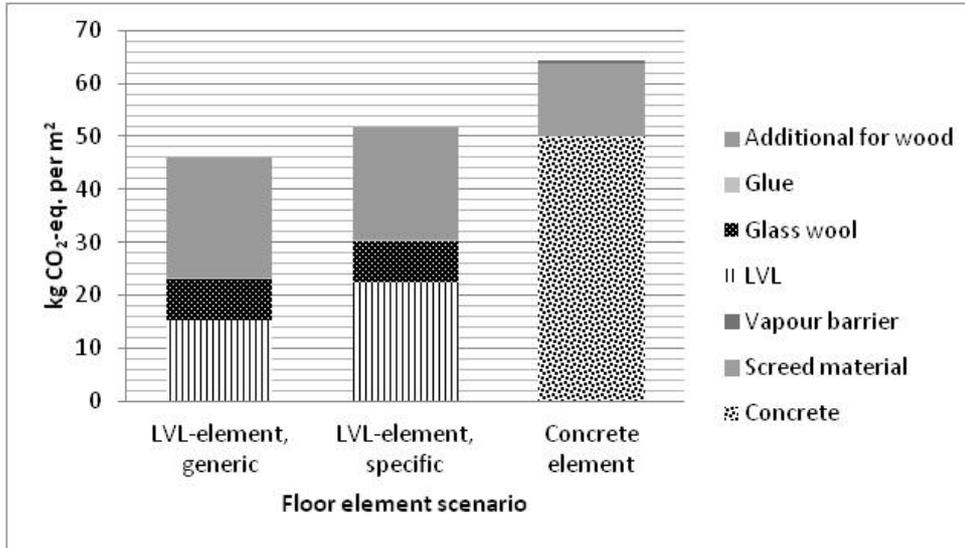


Figure 4: Comparing of floor elements at element level

Figure 5 shows that comparing of the LVL material and gluelam for both generic and specific data show large variation in total and in contribution of inputs. Both the generic show large contribution from wood inputs compared to the specific data. The contribution from glue shows large variation between all and especially between generic and specific inventory for LVL.

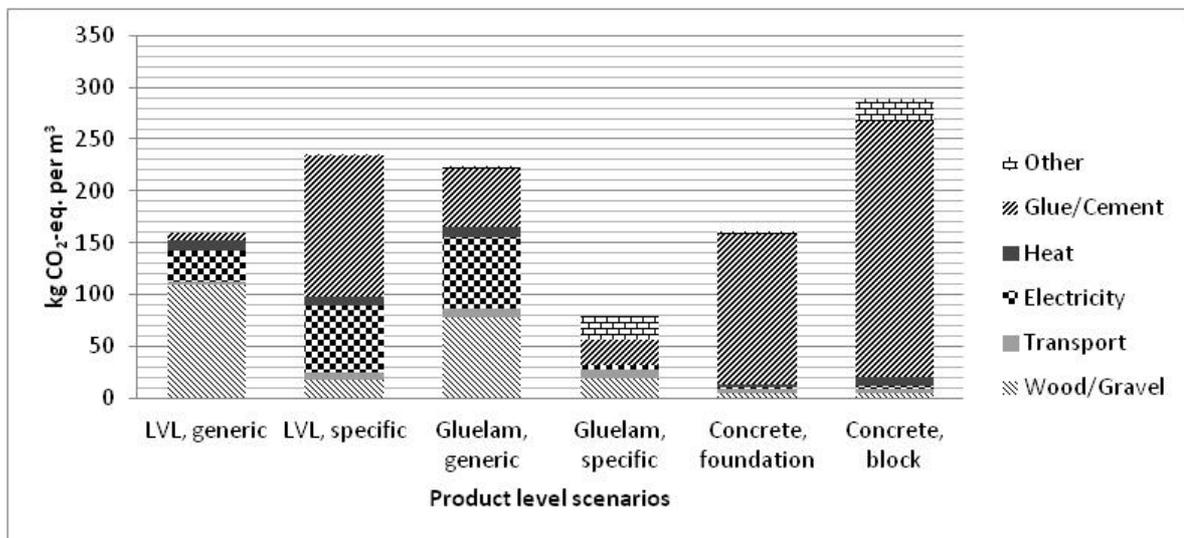


Figure 5: Comparing of wood and concrete materials at product level

The Norwegian produced gluelam differs itself from the other wood products by having a much lower total impact and especially the contribution of electricity is low. The concrete used in foundation is made of cement with blast furnace slag and has only 46% clinker, where the blast furnace slag is considered as a waste input. The cement in concrete on the other hand has 90% clinker at therefore considerable higher impacts (Ecoinvent 2010).



Discussion

The carbon footprint of the six-story building as built did not differ substantially between generic and specific data at building level. The difference was, however, quite large when the different materials were compared at product level and it seems that they cancelled out when aggregated to building level. The comparison at element level shows the importance of using functional equivalent where the materials that are needed in addition to wood in the floors are having a considerable impact.

The results showed that the foundation contributed significantly to the emissions of the building. One important reason behind using the Trä8 building system at this place was the low weight making it possible to use an existing foundation from a previous two-story building. Hence, the alternative building of steel and concrete would in reality require more foundation and thus have a higher carbon footprint. Another limitation of the material use in the assumed alternative steel and concrete scenario was that the length of the concrete hollow elements was the same as in the wood scenario. The concrete hollow elements have the strength to cover a length of more than double of this and this could lead to lower steel use.

This study has been limited to the production phase of the materials, but also of importance are the end of life scenarios of the building and especially benefits of recycling and energy recovery beyond the life cycle that are left out. The benefits of wood beyond end-of-life are heat recovery from incineration that is used either for industrial processing or district heating. One other aspect that could have large impacts of the carbon footprint of wood-based materials is the biogenic carbon flows. The wood-based materials are during growth in forest sequestering carbon dioxide from the air and this is stored in the product until decay or incineration during end of life. As suggested in prEN16485, the biogenic carbon flows will be included in the calculations for GWP for wood products that are sustainably sourced.

Conclusions

The building as built with the Trä8 system shows that the foundation is an important part of the emissions from the structure and an advantage of the light building frame of wood. When assuming the same foundation, the concrete and steel alternative building had 35% higher emissions of greenhouse gasses in production. The comparison at flooring elements between the as built version and a alternative with concrete hollow elements, shows the importance of comparing at functional equivalent in terms of requirements to strength, fire and acoustics. At product level the impacts of difference materials varies and especially with generic and specific data, but also the contribution to inputs such as glue.

Further work on the methodology for carbon footprint of wood buildings should be to include end-of-life aspects and the impacts of biogenic carbon flows. At the construction, optimization of materials that are needed in additional to wood in the floor elements and comparing the use of laminated veneer with laminated solid wood in flooring elements.

The practical implication of the results of carbon footprint of the Trä8 system should be to advocate the savings in both carbon emission and potential costs where foundation can be



reused because of the lightweight structure. This should be a growing potential with the increasing demand for urban dwellings and the need for higher buildings.

Acknowledgements

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Environmental Active Materials based on Natural Clays toward Quality of Internal Microclimate

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Abstract: *High quality of internal microclimate is one of the crucial requirements on high performance and sustainable buildings. The main goal of advanced building concepts is to achieve this quality while minimizing the energy consumption both in operation and construction phase. Clay minerals according to their specific mineralogical composition can help to improve the quality of internal microclimate due to their excellent hygroscopic properties. The structures based on natural clay can be used as a storage for interior moisture and can keep the required level of internal relative humidity suitable (40-60 %RH) without any additional energy demand.*

This paper summarizes the latest results of laboratory experiments of different building materials based on natural clay from the point of view of sorption properties. Numerical simulation using achieved laboratory results shows potential of using clay to improve quality of internal microclimate.

Keywords: *quality of internal microclimate; rammed earth; clay plasters, sorption properties; prefabrication; sustainable building*

Introduction

The building materials based on natural clay (e.g. clay plasters, rammed earth structures, earthen bricks etc.) belong to the wider group of “environmentally active” materials as for example PCM. The advantage of clay materials and earthen structures are low embodied energy, CO₂ and SO₂ emissions and full and easy recycling. The clay is also highly hygroscopic. This ability to effectively absorb and release moisture makes it an ideal material to moderate the indoor microclimate. Long-term stabilization of relative humidity influences positively occupant’s health [1] as well as durability of building structures.

Experimental verification of hygrothermal behaviour of clay and earthen materials is part of a long-term research project at CTU dealing with the development of prefabricated rammed earth panels [2]. This paper summarizes the latest results of laboratory measurements carried out within this project. Numerical simulations using these laboratory results verify the potential of clay materials to improve the quality of internal microclimate in buildings.

Sorption properties of rammed earth

Although natural clay has excellent sorption properties, in practical use clay materials contain certain amount of sand primarily to minimize the shrinkage cracks. However, the sand has practically negligible sorption ability compared with clay. The sand fraction in a typical clay plaster is between 70 and 75 %. Such a high amount of sand means that the sorption properties of clay plaster are at the same level as for traditional lime-cement plaster, as mentioned by Minke in [3]. On the other hand the sand fraction in unburned bricks and rammed earth structures usually does not exceed 30 %, which makes these structures more effective in terms of interior moisture moderation.

Within the the development of prefabricated rammed earth panels at CTU, the sorption curves of three rammed earth mixtures containing 0 %, 10 % and 30 % of sand were measured [4], see Table 1. The results are shown in Figure 1. In case of the mixture C_S30/W10 (30 % of sand) the sorption curve drops by 28 % compared with the reference mixture C_W10 (without sand). In case of mixture C_S10/W10 (10 % of sand) the drop is 12,5 %. Full-scale tests also showed that the mixture C_S10/W10 is well suitable for prefabrication of rammed earth panels, i.e. it guarantees their mechanical stability and does not cause excessive shrinkage cracks [2]. Clear comparison of the sorption curve of the rammed earth mixture C_S10/W10 with other commonly used building materials is shown in Figure 2.

Tab. 1. Rammed earth mixtures: (C – type of clay, W – water, S – sand)

Rammed earth mixtures	Sand amount by mass in %	Water amount by mass in %	Dry bulk density in kg·m ⁻³
C_W10	0	10	1 950
C_S10/W10	10	10	1 976
C_S30/W10	30	10	2 022

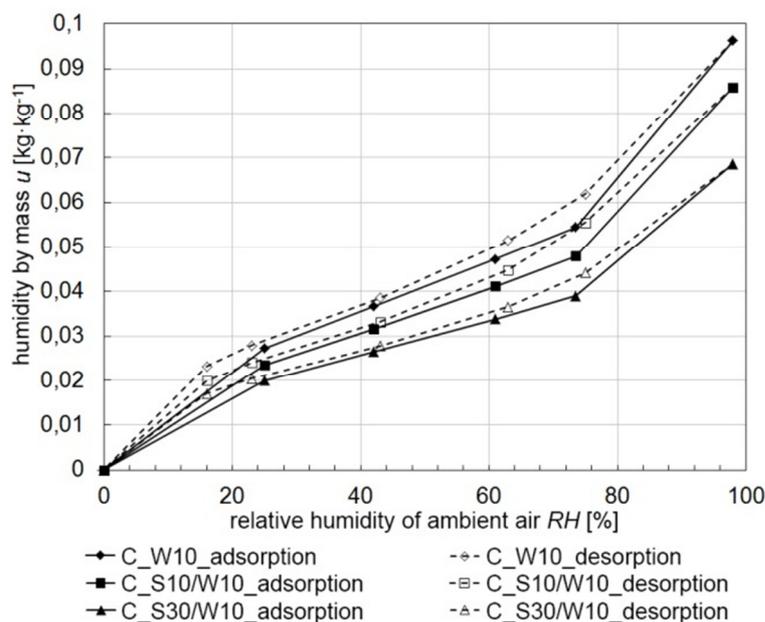


Fig. 1: measured sorption isotherms of rammed earth mixtures

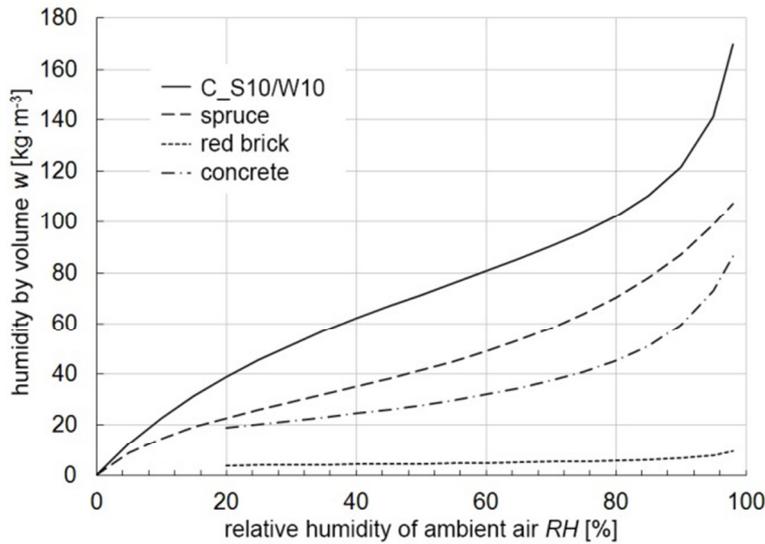


Fig. 2: sorption isotherm of rammed earth mixture C-S10/W10 in comparison with other building materials

Numerical simulation

Numerical simulation was used to assess the ability of rammed earth and three other common building materials (gypsum boards, concrete and red brick) to moderate the indoor humidity variations in a residential room. The materials were assumed to be uncoated. The aluminium foil is included as a non-absorbing reference material. The room geometry and boundary conditions used in the study are described in [5]. It was considered that all the wall surfaces are covered with the studied material being 12,5 mm thick. The floor and the ceiling were left with no sorption ability. The materials properties used in the simulation are summarized in Table 2. The properties of the rammed earth correspond to the mixture C_S10/W10.

Tab. 2: Material properties considered in the simulation

Material	Thickness	Diffusion resistance factor	Slope of the sorption isotherm	Dry bulk density	Moisture Buffer Value	
	<i>d</i> [mm]	μ [-]	ζ [g/kg]	ρ [kg/m ³]	g/(m ² ·%RH) @ 8h	
aluminum	12,5	1 000 000	0	2 700	0,00	negligible
gypsum boards		8	7	710	0,51	moderate
concrete		25	16	2 300	0,78	moderate
red brick		8	1,6	1 800	0,39	limited
rammed earth		10	48	1 970	1,98	good

The calculated courses of relative humidity in the room over a 48-hour period are presented in Figure 3. The rammed earth shows the strongest buffering effect resulting in the lowest daily humidity variations, below 9 % RH. Using a concrete layer of the same thickness results in daily variations of 15 % RH; in case of gypsum boards and red bricks it is 19 % RH and 23 % RH, respectively. Figure 4 shows the influence of moisture buffering of the materials in a longer term. The rammed earth keeps the indoor humidity within 28 – 48 % RH, while using the red brick results in variations between 17 and 63 % RH.

The simulation results showed that the rammed earth can effectively moderate the indoor air humidity variations; better than other commonly used building materials. It is due to the favourable combination of its material properties, i.e. low water vapour diffusion resistance factor (high water vapour permeability), high sorption capacity and high dry bulk density.

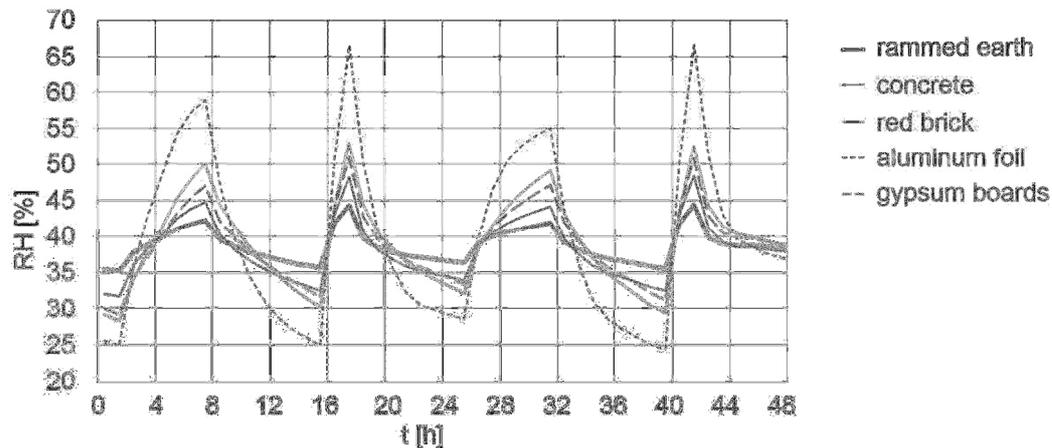


Fig. 3: Calculated course of relative humidity in the test room over a period of 2 days, all materials

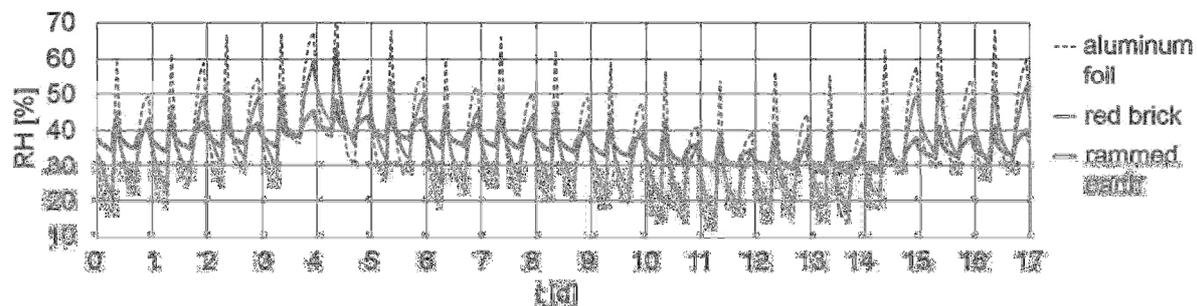


Fig. 4: Calculated course of relative humidity in the test room over a period of 17 days, selected materials

Examples of earthen structures to improve the internal microclimate

Several pilot projects show potential use of materials based on natural clay to improve the internal microclimate. Experience gained within these projects can be used for further development of earthen technology.

Passive family house in Pilsen, CZ

The technological process of prefabricated wall panels using rammed earth core and wooden frame was verified within the construction of a low-energy family house in Pilsen, CZ (2008) [6]. The building was designed as a timber-framed structure. The diaphragm interior wall was designed to perform as a heat accumulator. It consists of 16 prefabricated rammed-earth panels with dimensions of 950 x 650 x 200 mm.

The panels were manufactured using a stable wooden formwork, pneumatic rammer and electric air compressor. The construction of the wall started 7 days after the production of the last series of the panels. The wall of the total surface of 10 m² was built in 6 hours and then finished with clay plaster.



Fig. 5: Construction process of prefabricated wall from panels of the size 950 x 650 x 200 mm within the project of low-energy family house in Pilsen, CZ (2008), architect: AEROPLAN studio, rammed earth: CTU in Prague, Faculty of Civil Engineering, Department of Building Structures.

Passive family house near Prague, CZ

The aim of this project was to achieve wider criteria of sustainable building. The ecological footprint was reduced by using raw natural and renewable materials and minimizing of operating energy for heating, cooling and lighting. The building is designed in passive energy standard. It is based on timber-framed structure and an accumulating wall is made from industrially produced unburned bricks.



Fig. 6: Construction process of accumulating wall from unburned bricks in passive house based on 2x4 timber structure. Ptice near Prague, CZ (2012), architect: KUBUS studio.

Centre for ecological education, Slunakov, CZ

The ecological centre is run by the city of Olomouc as place for educating public about nature and relations of humans to natural environment. A part of the centre is a low energy building which built in 2005-07. It has an interesting structural and technology concept.

Architecturally it has an organic form composed into the landscape where the southern façade is opened for solar gains while the northern part is fully covered by the ground.

The southern part of the structure is designed from gluelam timber. It contains rooms for daily activities and the main corridor across the building. The rear part consists of concrete skeleton structure and lining from unburned clay bricks. Thanks to the energy conception the heating season is reduced to 4 months a year. The heat is distributed by a ventilation system (including underground pipe register), which is connected to two heat sources: low-flow solar system (85m² of solar collectors) and pellet boiler.



Fig. 7: Centre for Ecological Education in Slunakov (CZ). Concrete columns are combined with timber roof structure and with accumulating wall from industrially produced unburned bricks. Architect: PROJEKTIL ARCHITECTS, 2007.

New Ricola Herb Centre, Laufen, CH

The new Ricola Herb Centre was finished in 2013. The investor incorporated a number of sustainable ideas in one project. To ensure sustainable use of resources this new store is placed in close connection with other production buildings. The project was managed by company Kundert Planer AG in cooperation with Basel architects Herzog & de Meuron.

“The Herb Centre is built largely of locally sourced loam; it is like a geometrical segment of landscape with its dimensions and archaic impact heightened by the radical choice of material.” [7] In the stocking part, the earthen panels are the only coat of the building. Earth is designed here to control the internal climate and create stable conditions during all seasons. The rammed earth façade was prefabricated in a nearby factory by Lehm Ton Erde led by Martin Rauch. All material resources were obtained locally. Clay material excavated on site was mixed and compacted in formwork and then layered in blocks. Blocks were transported to site and assembled precisely to create continuous layers of compacted earth. Furthermore, volcanic tuff (trass) was mixed with cement and used in some of the layers to decrease erosion caused by wind and rain. The façade is self-supporting and simply joined to the concrete loadbearing structure of the interior.



Fig. 8: Ricola Herb Centre in Laufen (CH). In the stocking part earthen panels are the only coat of the building. Earth is designed to create stable interior microclimate during all seasons. Architect: HERZOG & de MEURON ARCHITECTS, 2012.

Conclusions

The topic of sustainable building covers wide range of issues including environmental, socio-cultural and economic criteria. Quality of internal microclimate is one of the crucial criterions of the overall quality of the building. Clay material and earthen structures represent one of possible approaches to meet the needs of higher quality of internal microclimate with positive impact to increase operating energy for mechanical moistening.

The presented experimental results, mathematical simulation and also the practical examples show the rammed earth and other earth structures can effectively moderate the quality of



indoor climate in terms of air humidity; better than other commonly used building materials. However, interior coating is often necessary in practice. Improper surface material can significantly decrease the performance. Therefore, the further research will be aimed at coating options for rammed earth panels in order to keep their high moisture buffering capacity.

Acknowledgment:

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Where is the embodied CO₂ of buildings mainly located? Analysis of different types of construction and various views of the results

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Abstract: *A set of four buildings with different types of construction was analysed using a Life Cycle Assessment (LCA) in order to identify the main contributors to overall embodied carbon emissions. The results are presented by virtually “cutting” the buildings in two different ways, focusing not only on the building as a whole, incorporating all its various materials, but also on the individual impact of each building element (floor, ceilings, external walls, etc.) on the one hand, and on the impact of a predefined standard enclosed floor space (e.g. basement space, typical floor space, roof space) on the other. As a result, different perspectives and levels of detail are covered in the critical impact evaluation of each building, giving a thorough and comprehensible answer to the question of where the embodied CO₂ of the buildings is primarily located. The allocation of carbon emissions to the floor space of each storey, instead of to the floor space of the whole building, demonstrably produces relatively homogeneous results, which facilitate the comparison of the buildings from the sample and their diverse characteristics.*

Keywords: *buildings; carbon emissions; different types of construction; different perspectives*

1. Introduction

Life Cycle Assessment (LCA) has been established as an effective method for evaluating the environmental impact of products and services over their lifecycle. The general LCA procedure is described in the ISO regulations 14040 [1] and 14044 [2]. For LCAs of buildings, the DIN EN regulation 15978 [3] gives a more detailed description of the aspects that require particular consideration in the context of a building. Despite many efforts in recent years to simplify the rather complicated LCA procedure for buildings, in order to make it more easily applicable to the needs of architects and planners, there are still various challenges to be met. An essential one of these is the presentation of LCA results in a way that clearly provides valuable information for the architect regarding which building elements contribute most to the overall environmental impact of a building. As architects characteristically have a strong visual perception of the built environment, it is crucial to provide them with more than just a numerical analysis of a building's environmental impact in order to help them advance their building designs. A thorough and comprehensible answer to the question of where the embodied CO₂ of the buildings is primarily located requires a critical impact evaluation of a building that incorporates different perspectives and different levels of detail. The key to addressing this challenge and to facilitating LCAs of buildings could be the definition of the functional unit in a more intuitive way than is usually applied in existing studies. The functional unit is the unit to which all inputs (resources, energy) and outputs (waste, emissions), as well as the environmental impact results of an LCA refer. In this paper, the

authors utilize two different functional units: one is a functional unit commonly applied in many existing LCA studies of buildings (1 m² of general floor space per 1 year of the building's lifetime); the other is a functional unit that corresponds to 1 m² of a specific floor space (basement, ground floor, upper floor or loft) per 1 year of the building's lifetime. A building sample of four individual apartment buildings is analysed in a comparative LCA and the results for the embodied carbon emissions of each building element are displayed for both functional units. Two different virtual cutting approaches for the buildings are required in order to properly determine the emission results of the two functional units. A schematic view of the second cutting approach helps visualize the different concepts. In chapter 2, the characteristics of the four buildings from the sample are introduced, followed in chapter 3 by the LCA modelling specifications, which were applied for the calculation of carbon emissions. In chapter 4, the two different approaches to virtually cutting the building are described and in chapter 5, the carbon emission results for both functional units are presented, followed by the conclusion and discussion in chapter 6.

2. Characteristics of the building sample

The building sample consists of four apartment buildings with diverse characteristics.

Building 01 is the largest of the four buildings. It contains 111 accommodation units and is a massive construction, mainly of reinforced concrete (floor, ceilings, external and internal walls, roof) and concrete block (internal walls). Insulation materials are the following: recycled glass foam fill, expanded polystyrene, polyurethane foam, mineral wool, and extruded polystyrene. There are five floors above ground and one basement floor (including underground parking spaces). The building has a flat roof planted with vegetation. The energy reference area of this buildings is 12 430 m².

Building 02 is a medium-weight construction and contains two accommodation units. The construction is mainly of reinforced concrete (floor, ceilings, external and internal walls), timber (ceilings, external and internal walls, roof), and sand-lime brick (internal walls). Insulation materials are the following: mineral wool, recycled glass foam fill, extruded as well as expanded polystyrene, and polyurethane foam. The building has three floors above ground and one basement floor. It has a pitched roof clad in fibre cement. The energy reference area of this building is 350 m².

Building 03 is a lightweight construction containing three accommodation units. The construction materials are timber (ceilings, external and internal walls, roof) and reinforced concrete (floor, ceilings, external and internal walls). Insulation materials are the following: mineral wool, recycled glass foam fill, foam glass and cellulose fibres. There are three floors above ground but no basement. The building has a flat roof planted with vegetation. The energy reference area of this building is 374 m².

Building 04 contains four accommodation units and is a massive construction. The materials used for the main construction are reinforced concrete (floor, ceilings, roof) and masonry (external and internal walls). Insulation materials are the following: expanded polystyrene and

polyurethane foam. There are two floors above ground and one basement floor. The building has a pitched roof clad in galvanized sheet steel. The energy reference area of this building is 622 m².

Details of the building characteristics can be found in the descriptions of mfh01, mfh02, mfh03 and mfh04 in the dissertation by V. John [4].

3. LCA modelling specifications

The carbon emission results were calculated using the professional LCA Software SimaPro [5] (version 7.3.0) with the implemented LCI database Ecoinvent [6] (version 2.2). The values indicate the Global Warming Potential GWP 100a (IPCC 2007 GWP 100a V1.02 [7], referring to a time horizon of 100 years for emissions). Included in the calculations are all materials required for the construction, replacement and deconstruction of the building elements (floor, ceilings, external and internal walls, roof, external doors, and windows) over the building's lifetime of 60 years. It is assumed that the main construction materials have a service life of 60 years, while all other materials need replacement after 30 years (with some minor exceptions). All LCA modelling specifications for the buildings can be found in the appendix of the dissertation of V. John [4].



Figure 1: Surface areas of the building elements and their shares per individual storey

4. Approach: virtual cutting of the buildings

For the presentation of carbon emission results for the four apartment buildings, two different virtual cutting approaches have been chosen for comparison.

Virtual cutting approach 1

The first approach aims at breaking down the total kg CO₂ eq of each building to the functional unit of 1 m² of general floor space (in this case the energy reference area) for 1 year of the building's lifetime. This approach is commonly utilized for LCAs of buildings and facilitates a general comparison of the four buildings by levelling out the huge differences in building sizes. It is, however, not the best way of showing clearly where exactly the main contributors to the final result are situated within the building. When looking at a building from an architect's point of view, there is no such thing as a general 1 m² of floor space to which the overall building emission results could be meaningfully allocated. Instead, each storey has its individual contributors to the final result. The floor element, for instance, only contributes to the lowest building storey, while the roof element normally only covers the top storey. Furthermore, the exterior door is usually on ground floor level, while external and internal walls are found on all storeys.

Virtual cutting approach 2

Consequently, the second approach to virtually cutting the buildings aims at systematically defining four typical storeys within a building according to their specific, typical characteristics. The carbon emissions are then calculated for 1 m² of this specific floor space for 1 year of the building's lifetime. The characterisation of the storeys follows some simple rules defined by the authors:

Loft

The top storey of the building, defined as consisting of the elements roof, ceiling (at the bottom of the space), windows, and external and internal walls.

Upper floor

The storey(s) between ground floor and loft, defined as consisting of the elements ceiling (at both the bottom and top of the space), windows, and external and internal walls.

Ground floor

The first storey above ground, defined as consisting of the elements ceiling (at both the bottom and top of the space), external doors, windows, and external and internal walls.

Basement

The storey below ground, defined as consisting of the elements floor, ceiling, and external and internal walls.

Within the building sample, two exceptions from these rules were found in the buildings 01 (where, due to the underground parking space, the roof element had to be partly allocated to the basement) and building 03 (where the basement is missing, so that the floor element is allocated to the ground floor instead).

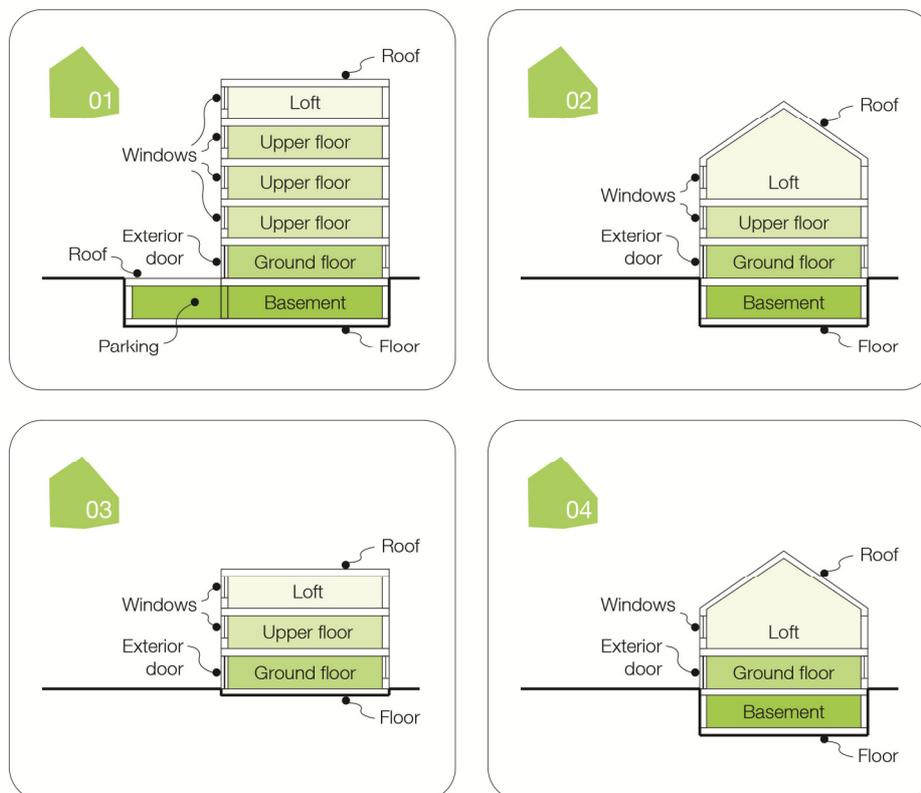


Figure 2: Schematic view of the floor space characterisations for the virtual cutting approach 2

To enable easy and consistent calculation of the individual shares of each building element per storey, the total surface area of each element was divided by the number of events in which it occurs in the building. For instance, in building 01, there are five ceilings within the whole building, as can be seen in the schematic vertical sections in Fig. 1 and Fig. 2. This means that for each event the share of the ceiling is 20%. When computing the values for the ground floor storey, this leads to a total contribution of 40% of the total ceiling surface area, as there is a ceiling element on top as well as on the bottom of this storey. It is worth mentioning that the splitting of the buildings into the four aforementioned storey types leads to the ceilings being counted twice, so that, in the end, the sum of the results for all the storeys of one building is higher than the original total result for that same building. However, this is unproblematic, as this approach aims at comparing the characteristics and embodied emissions of each individual storey rather than those of the whole building. The total surface areas, as well as the shares of all element contributions for each storey, are shown in Fig. 1. Fig. 2 illustrates the main characteristics of each of the buildings from the sample.

5. Carbon emission results for the two different cutting approaches

5.1 Results for virtual cutting approach 1

Fig. 3 shows the results of the embodied carbon emissions analysis for each building element of each building, using the unit kg CO₂ equivalents per 1 m² of energy reference area for 1 year. The graph shows clearly that with this virtual cutting method there is much variation in the distribution and relevance of the results for the different elements. While in buildings 01

and 04 the ceilings and the roof contribute the most to the overall environmental impact of the building, for building 02 the external walls and ceilings are most influential and for building 03 it is the roof, windows, floor and ceilings that affect the result most significantly. These graphs reflect the high degree of originality of each building, emphasising its individual characteristics in comparison with the others.

5.2 Results for virtual cutting approach 2

The graphs in Fig. 4 show the results of the second cutting approach and allow a clearer understanding of where exactly the most significant carbon emissions are located within the building. In the graph at the top left-hand corner of Fig. 4, the results for the annual embodied emissions are shown for each of the buildings per 1 m² of individual storey floor space of the basement, ground floor, upper floor and loft respectively. Viewing the building elements in this way, the four buildings display fewer individual differences and a more consistent distribution of the carbon emission results than was observed in Fig. 3 using the first cutting method. Of the four buildings, building 01 has the highest carbon emissions for each storey. The percentage values displayed below this graph indicate the differences in environmental impact of the other three buildings from the sample in comparison with building 01. For the basement, the differences in the results of the four buildings vary by a maximum of 27%, the results of the ground floor by 33%, the upper floor results by 41%, and the loft results by a maximum of 56%. The individual contributions of the building elements per storey are shown in the graphs at the bottom of Fig. 4. The generally high influence of the ceiling and roof

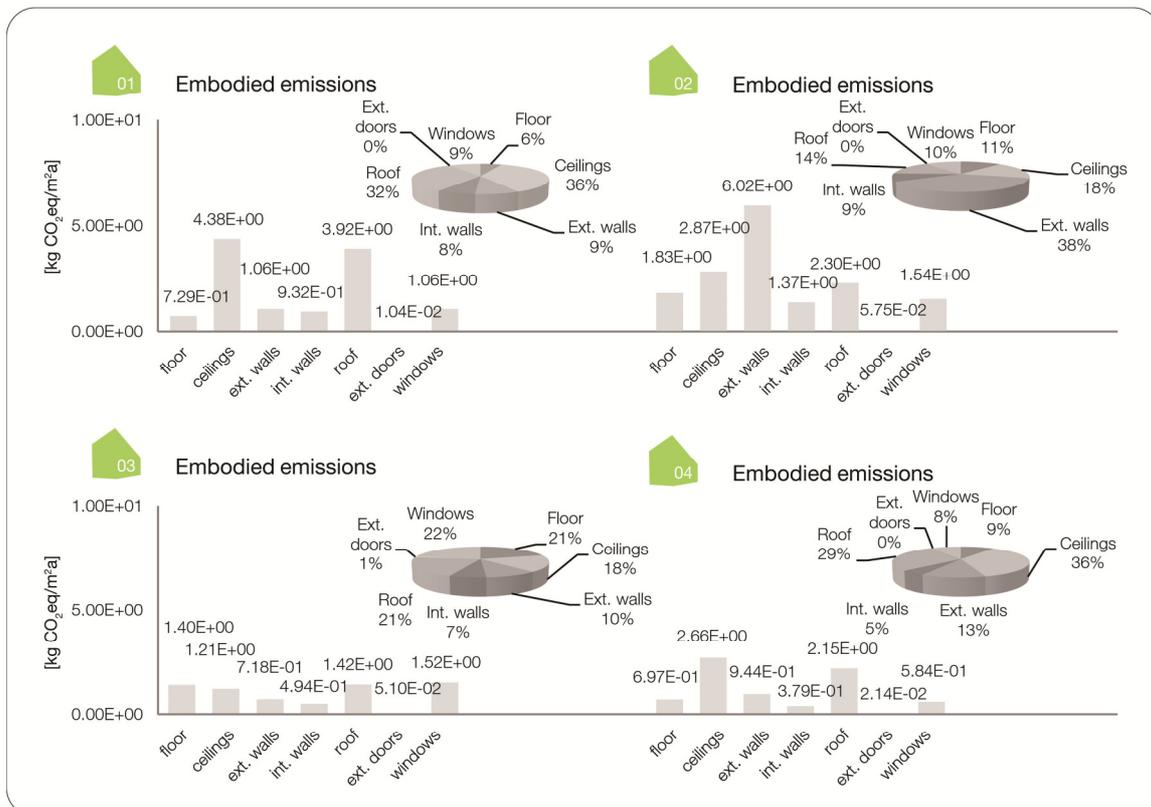


Figure 3: Embodied carbon emission results (virtual cutting approach 1)

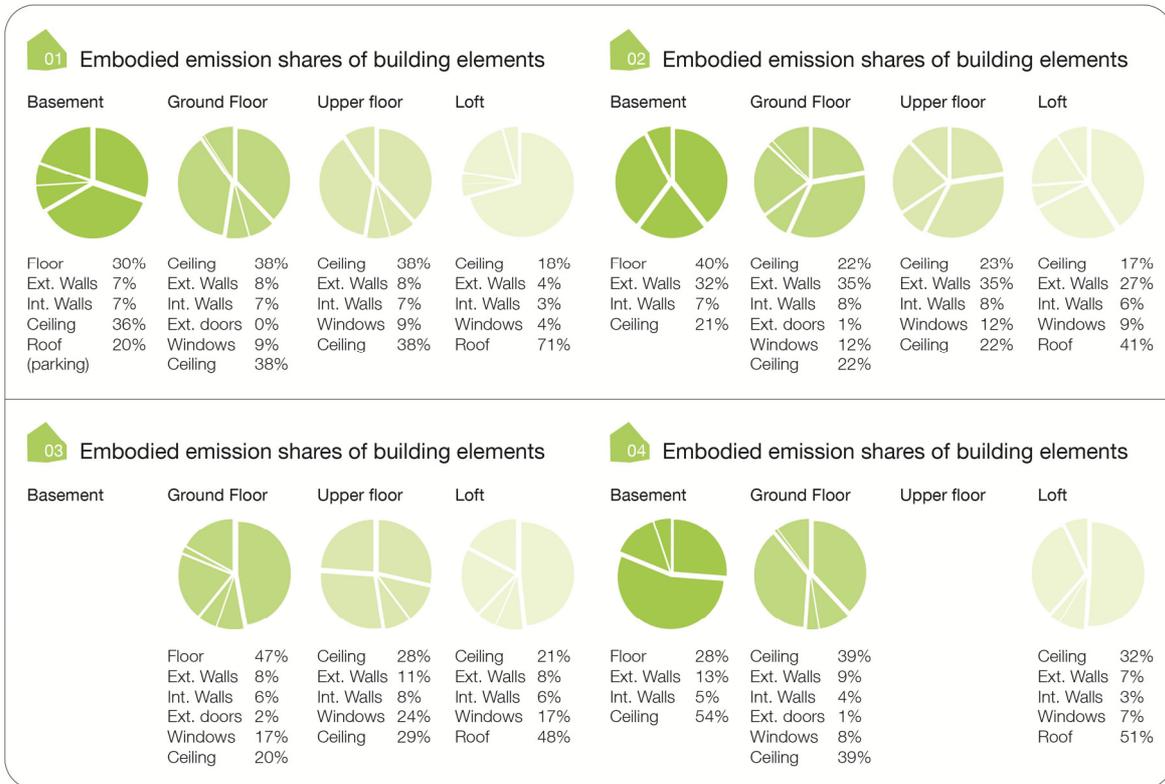
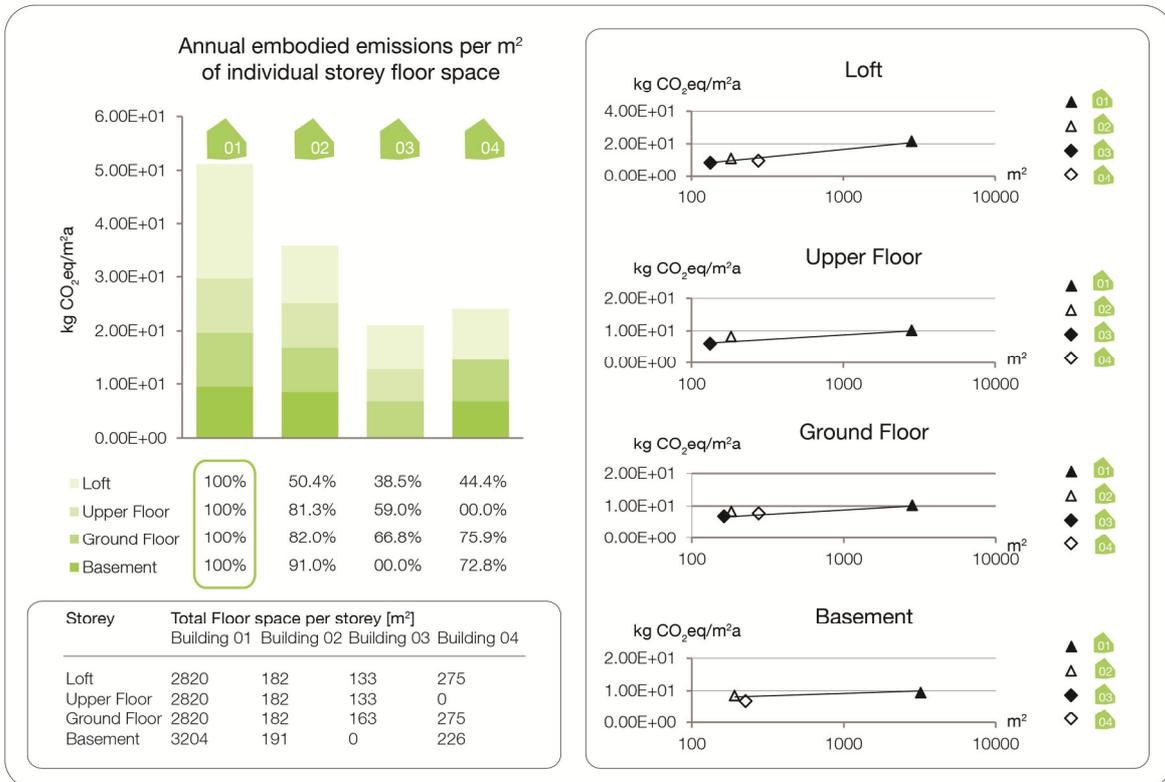


Figure 4: Embodied carbon emission results (virtual cutting approach 2)

elements for the buildings 01 and 04, the dominant influence of the external walls and ceilings in building 02, as well as the influence of the roof, windows, floor and ceilings in building 03, are also apparent with this second cutting approach. Nevertheless, the buildings resemble each other much more closely when comparing the pie charts of each of their storeys individually than when comparing the buildings as single units. It can be observed by comparison of Fig. 3 and Fig. 4 that by cutting the building into different storeys a more detailed depiction of the embodied carbon emissions for each individual building is obtained, while at the same time a higher degree of similarity within the building sample is perceptible. This enables the determination of the embodied emissions for an average square metre of a basement, ground floor, upper floor and loft. It can be stated, that for this particular building sample a typical square metre of basement contributes $8.07 \text{ kg CO}_2\text{eq/m}^2\text{a}$ ($\pm 16\%$ deviation) on average, while for the ground floor it is $8.48 \text{ kg CO}_2\text{eq/m}^2\text{a}$ ($\pm 20\%$ deviation). The upper floor accounts for a mean of $8.04 \text{ kg CO}_2\text{eq/m}^2\text{a}$ ($\pm 26\%$ deviation) and the loft contributes $14.86 \text{ kg CO}_2\text{eq/m}^2\text{a}$ ($\pm 45\%$ deviation). Apparently, the basements, ground floors and upper floors of the four buildings have nearly the same environmental impact on average, while the lofts exhibit the largest deviation in their results.

The four graphs at the top right-hand corner of Fig. 4 show the amounts of embodied emissions per 1 m^2 of individual storey floor space for 1 year (y-axis) and the total size of the storey floor space (x-axis) for all four buildings together. For this particular building sample, there appears to be a linear trend, indicating that an increase in total storey floor space leads to an increase in the annual embodied emissions per 1 m^2 of individual storey floor space. However, in order to verify this trend, it would be essential to analyse more buildings, preferably with an energy reference area of $\geq 1000 \text{ m}^2$, as there is a huge gap in the divergence of the sizes of the buildings 02, 03 and 04 on the one hand, and building 01 on the other.

6. Conclusion and discussion

The presented approach of virtually cutting the buildings from the sample in two distinct ways helps to clarify the interrelations of the different individual parts of the buildings within their overall functional context. While the first functional unit can be utilized in order to get a broad view of the embodied carbon emissions of the various building elements of the whole building, the second functional unit enables a more sophisticated allocation of the results, with regard to the anticipated location of the most relevant elements per storey. In their combination, the two approaches allow a meaningful presentation and interpretation of the impact of each of the building elements by showing them from different perspectives and with different levels of detail. It can be observed that the second virtual cutting approach shows fewer individual differences and a more generic distribution of the carbon emission results of the four buildings compared with the results of the first cutting approach. This second approach thus helps to derive a comprehensive and intelligible answer to the question of where the embodied CO_2 of the buildings is mainly located, and, beyond that, helps determine the embodied emissions of an average square metre of basement, ground floor, upper floor and loft with a minimum and maximum deviation from the mean value. As the buildings



within the depicted set exhibit a high level of variety with regard to their construction types and the embodied carbon emissions of their individual building elements, the rather high degree of homogeneity of the results as displayed by the second virtual cutting approach is especially remarkable. It was demonstrated that by schematically cutting the buildings on the basis of only a few simple conceptual assumptions about the specifications of each storey, a consistent comparison of a set of diverse buildings is feasible, and that quite similar results can be generated from the direct comparison of the same storey of the various buildings. It was shown, that the carbon emissions results per specific storey floor space of the basements, ground floors and upper floors of the four buildings are nearly the same on average (around 8 kg CO₂eq/m²a), while the loft exhibits a significantly larger variation in the results than the other storeys. This finding might help in roughly estimating the impact of a standard storey of a building. Determining the impact of a standard storey of basement, ground floor, upper floor and loft can help architects and planners to quickly evaluate the performance of their building design using these values as benchmarks, enabling them to localize which storey and which building elements bear the highest optimization potential for their specific project.

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Session 103:

How can we transform specific goals into urban scale strategies?

Chairperson:

Velázquez, Isabela

Directora de proyectos de Gea21



An Exploration of Law Instruments in Kaohsiung Sustainable Actions: Taking Kaohsiung City Green Building Autonomy Act for example

Speakers:

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Abstract: *After Kaohsiung City merging with surrounding Kaohsiung County and thus expanding in scale in 2010, Kaohsiung city has the characteristics of multi-ethnic, diverse landscape, and distinctive cultures. The promotion of the action plan for Kaohsiung building environment transformation is based on the planning of the residential and commercial sector. A periodical approach was used for plan promotion according to various topographical and cultural environments, stressing local culture, green buildings, and citizen participation. Relevant laws were established to ensure the practical implementation of the transformation plan. This plan enables a reconsideration of cultural positioning and corrects the development of built environments. By adopting a core positioning of water and greenery, the concepts of ecology, economy, livability, creativity, and internationality are used to remold the living environment of Greater Kaohsiung. Thus, along with the citizens of Kaohsiung City, we participated in the action plan for sustainable building environment transformation. "Kaohsiung City Green Building Autonomy Act" is the National Capital Act to make the green building standard higher than the central ones. By stipulating the green building design of equipment and facilities, the act laid the technique foundation of environment control for the meaning of Kaohsiung citizen's green life. Moreover, it shows our responsible attitude to deal with the issues of climate changing and high carbon emissions. The thesis explores many directions of the act, including the legal institution process, the strategy of awarding and forcing working together, the financial resources raised by the creation of green building development fund, the benefit analysis of building license applications for the past two years. At last, this propose is to advise the act in connection with the complex issues of urban conservation, public participation. There is an important reference value to solve the problem of citizen's livelihood and improve the quality of life.*



Keywords : *The Actions of Sustainable Building and Environment Reforming in Kaohsiung, Kaohsiung City Green Building Autonomy Act, Livable Life*

1. Introduction

After the merger of Kaohsiung county governance range 2946 km², a vertical elevation 3500 meters above sea level, with a multi-ethnic, diverse landscapes, urban and rural culture with distinctive characteristics. In response to sustainable development, disaster prevention and other needs in the face of industrial pollution, the elderly birthrate, industrial exodus, urban and other complex issues disappear historical features, new buildings must have innovative Kaohsiung value and meet the expectations of the public towards.

To establish a subtropical climate zone new paradigm of low-carbon cities livable city government, the Executive Yuan has been awarded "eco-city program to promote green building" with a series of low-carbon action. Following the above, new and existing buildings in Kaohsiung apply "smart green building improvement" on the green building technology research and promotion. And with the implementation of the building set "three-dimensional green" buildings as a "Sunshine Community" and legal counseling illegally built into tin roof "photovoltaic roof-top" and other projects and innovations Act.

However, the government's policy tool: Act peremptory norms of urban style and cultural preservation under the same whether positive improvement. How to upgrade the industry to deal with sustainable development? The motivation of this paper is to discuss urban life of ordinary people saved contradiction with the complex range of issues of mutual influence.

2. Kaohsiung green building autonomous regulations

As the city's carbon dioxide emissions per capita for the country's highest city, how to reduce the damage to the buildings of the city environment and to follow the relevant provisions apply outside the central green building, and according to the city's special climate conditions, Kaohsiung develop higher than the central regulation of carbon reduction standard and green building requirements to expand the effectiveness of carbon reduction. The goal of transformation of city into "the people-oriented, disaster prevention, green energy, industry" concept as environment friendly has been created "from enhancing the construction industry to promoting sustainable urban aesthetics and construction Environment" win-win situation. Kaohsiung green building autonomous regulations were announced 18th June, 2012, and implementation in the same year on 1st July.

2.1 Contents of Kaohsiung City Green Building Autonomy Act

"Kaohsiung City Green Building Autonomy Act" was integrated urban climatic conditions of Kaohsiung, such as high temperature; high humidity and abundant sunshine. In response to environmental issues on Kaohsiung buildings, including insulation, urban heat island effect and storm flood control, can be achieved the local characteristics of green building and the goal of building carbon reduction and mitigation on water saving, power reduction, citizen

health, and environmental protection. This Act regulates all public and private buildings for public use, and includes the use of existing buildings for change. The green building codes have various criterias for different building sizes. The items include solar photovoltaic and/or greens roof top of the building, enhance thermal insulation, temporary garbage storage facilities, water-saving toilet, rainwater and gray water recycling system, storm water catchment tank, improvement of the use of green building materials, and bicycle parking spaces and elevators etc.

In addition to setting related to green building codes, the autonomous regulations also provide incentive grants related measures and regulations relaxed, for example: green building construction permits a reduction in the application of the provisions of fees, city budget subsidies folk green construction, Awards the deep balcony and three-dimensional greens set, and green building related facilities free application method miscellaneous licenses and other sources etc. These will greatly enhance the willingness to set builders with green building facilities to achieve a win-win for the environment and industrial situation.

2.2 Benefits of Kaohsiung green building autonomous regulations

In response to the instantaneous rainfall and increased building disaster prevention capabilities, Active in green building city ordinances and demonstration projects on “Green Roof” were introduced. From 2011 to 2013, The benefit is to complete seven cases in six places of public buildings green roof demonstration cases, which includes Kaohsiung City Art Museum (Figure 1), the Shin-Shing Branch of police station next to MRT O5R10 Stop, Kai-Shieng Hospital, Fengshan Eastern Revenue Service Office, Kaohsiung Labour Bureau, San Min District Office photovoltaic farm (Figure 2) etc. Total green area obtained 4,623 m². The private sector applied green roofs total 213 cases and the green area of 65,500 m². A total of 1,402.64 tons of carbon emissions reduced in three years. Recently, the annual goal on green roof settlement targets 30,000 m² which equals carbon sequestration capacity of 600 tons per year. The scattered areas set up to help micro detention and increased urban sponge function, than fundamentally prevent the urban flood.



Figure 1 Roof greening project of Kaohsiung City Art Museum



Figure 2 Roof PV Farm of San Min District Office



In 2013, the amount of 230 construction license were applied to green building applications, accounting for 5.98% of the full year of construction permits of 3848 applications. These 230 green buildings face the resulting environmental benefits include: green roofs settlement achieved the area of 31,788 m², increased solar photovoltaic power generation facility set 4,616 peak kilowatts (Kwp), which was Equivalent to 4.6 Kaohsiung Main Stadium of World Games, increased bicycle parking spaces 1657 seats and bike affiliated shower area 239 m², the rainwater harvesting tanks were set up about 16200 m³, the installation of energy-saving lamps set the total 1,630.7 KW, which rovincial power had 815.3 KW, the buildings have required to set rainwater catchment and water recycling facilities up to 13,200 tons per year to effectively mitigate urban storm, which the equivalent of six new standard pool capacity annually.

3. Award requirements - photovoltaic building ordinance

Kaohsiung City Government in order to pursuid the environmental sustainability and also to follow the Central Government Policy on “strengthen energy conservation and carbon reduction, the development of clean energy, expanding green industry, green energy and recycling applications in urban and rural construction”, established the country's first photovoltaic building ordinance. The aim is to face the view of Kaohsiung climate “abundant sunshine”, creative skyline “hut lined”, problem of heat island “less green parks”, carbon emissions “carbon dioxide emissions in the top of the nation”, and citizen needs “roofing insulation facilities”. Kaohsiung City Government has promoted the application and development of solar photovoltaic facilities as a major policy.

3.1 Contents of Kaohsiung Act of photovoltaic building

“Kaohsiung building roof solar photovoltaic facility setting approach” was issued and implemented on 26th April 2012. Connection also completed “Kaohsiung photoelectric smart building label certification approach” and “Kaohsiung City Government solar photovoltaic facilities executive task-force guidelines”. The above acts were customized as all the country's first local ordinance. The criteria stipulate photovoltaic facility with the height 4.5 m below, and an area less than 50 % of gross floor area can be free account its height and area. After 2013, the solar PV roof can be set and covered the whole area of a roof , terrace and roof projections can also be attached.

3.2 Benefits of Kaohsiung Act of photovoltaic building

Municipality actively promoted solar photovoltaic and the first smart community with photovoltaic roof of 4.5 m height has been completed (Figure 3), and BIPV sunshine factory has also been completed and opened (Figure 4). The building numbers of solar photovoltaic applications was top four of Taiwan in 2011. After the implementation of the photoelectric Act, the number of applications was 280 in total of 2012 as the top one city in Taiwan. The ratio was about 19.8 % of the country's total number of applications with a striking result. The total capacity is set up to 15,335 KW. In 2013, the city's total number of cases to apply was

571 (growth rate of 204 %), the same first highest number of cases nationwide application with a total capacity of up to setting 23,995 KW.



Figure 3 Kaohsiung first smart community with PV system



Figure 4 Kaohsiung first BIPV Sunshine Factory



Annual generation capacity of 19.92 million kWh and carbon reduction amounted to 12,400 tons which were equivalent of 587 hectares of forest carbon absorption measurement. The solar photovoltaic life up to 20 years, These set in Kaohsiung current total capacity approximately 40.546 MW to estimate a total reduction of about 600,000 tons of carbon dioxide in 20 years, which means the carbon sequestration benefits equivalent to an area of about 30,000 hectares of forest absorbed with an afforestation cost savings equal to \$ 100 billion. Taiwan also reduced for about 1.1 billion carbon tax. These settings can also be avoided photovoltaic facilities illegally built a new generation and gradually changing the existing rooftops chaos.

4. Conclusion and Recommendation

4.1 Conclusion

Kaohsiung in recent years to develop a low-carbon measures to spare no effort, including industrial zone integration, the use of solar energy, public bike settings, promotion of low-carbon green energy, construction of bike paths, wetland ecological corridors etc. Actively seek to uniquely Asian International Committee for Local Environmental Initiatives (ICLEI) Kaohsiung environmental sustainability capability training centers, and to cooperate with the International Initiative for a Sustainable Built Environment (iiSBE) on the verification of Kaohsiung green building project. Promoting environmental sustainability proved Kaohsiung strength of the transition to a low carbon green city.

The actions of Kaohsiung toward the sustainability are fruitful. Kaohsiung was named as the one of five Asian cycling center obtained from CNN, and the projects of “Heart of Love River”, “Chau-Tsai Wetlands”, “Lin-Pi Wetland Park”, and “Chung-Tu Wetland Park” successively won the “Construction of the World's Excellence Award” from World Real Estate Federation (FIABCI). The Sustainable Development Action in 2013 was obtained a “Sustainable Environment and Harmonious Society” Outstanding Group Award and Healthy Cities Award from the central government “Executive Yuan” of Taiwan. Furthermore, Kaohsiung public constructions and projects got 4 Gold, 3 Silver and 3 Bronze Medals of “International Livable City Award”, which was organized by the United Nations Environment Programme and has said as “Global Green Oscar” (Figure 5). These represents the achievements of Kaohsiung City Government in promoting ecological construction obtained worldwide recognition, involving the issues on urban plan, community environmental management, and sustainable development of natural resources.



Figure 5 International Awards for Livable Communities 2013

4.2 Recommendation

In summary discusses the strategy of sustainable development in Kaohsiung city preservation of content and meaning, made the following recommendations:

1. Sustainable development strategy will need to reflect the true lives of ordinary people: Kaohsiung City Government will continue in the environmental reform movement, the implementation of sustainable buildings should balance between the decree to develop goal-oriented tools and the designers' creation on the aesthetics of life. Urban and architectural style should return to local conditions, ethnic settlement culture, the nature of social life, and the public participation to opinion feedback.
2. The central government should create laws to fully empower local urban and rural landscape of elasticity: The implementation of the policy, public sector often utilize the integrated decree tools and resources. Local government should try to integrate urban design and construction management departments of the ambitious reform efforts worthy of recognition for the Kaohsiung urban and rural landscape. "Viewing globally, Acting locally" means that the the central law and building codes of the construction and management should give more authority of the criterias for local circumstances and local government should carefully autonomy to set construction management regulations,

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Embedding sustainability considerations within the strategic and operative management of real estate organisations

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Abstract: *During the past decade, a largely shared and relatively sound understanding of what sustainability means in relation to both, buildings and organisations has been developed within the real estate industry. Based on this understanding, systems for the sustainability assessment of buildings and for sustainability reporting of organisation have emerged. To a large extent, however, this took place remote from regular business routines. Also, the impact of sustainability-related building performance on overall organisational success has not often been fully embraced. Today, sustainability is increasingly seen as an organisational success factor. This paper illustrates how sustainability aspects can be integrated into regular decision-making processes and information flows at different hierarchical levels. A framework for an integrated approach – i.e. a corporate real estate sustainability management (CRESM) system – is briefly described. The paper draws upon and further develops ideas contained in a recent report written for UNEP FI by the authors of this paper.¹*

Real estate industry, decision making, key performance indicators, information flows

Understanding sustainable development within the real estate industry

The basic principles, objectives and management rules of sustainable development are very generic and broad. They therefore need to be transformed into a system of measurable criteria in order to be manageable. This applies for different assessment objects (e.g. buildings) as well as for different industries (e.g. real estate). The requirement for applying sustainable development principles to the construction and design of buildings follows the tradition of environmental and health-conscious construction of the 1970s and 1980s and integrates design principles such as design for environment or design for deconstruction. As a result of the efforts of international and European standardisation at ISO² and CEN³, a sustainable building is nowadays understood as a building that (a) meets current and future requirements regarding functional and technical quality, (b) ensures the health and comfort of users, has a superior design and quality of urban planning (social performance), (c) reduces the use of resources and minimises environmental impact (environmental performance), and (d) has low life cycle costs in addition to a positive contribution to the stability and development economic value (economic performance).

For existing buildings, such performance / quality aspects can be assessed and continuously monitored during the use phase in order to achieve continuous improvement. For this reason,

¹ See: UNEP FI, 2014, *Sustainability Metrics – Translation and impact on property investment and management*, United Nations Environment Programme Finance Initiative, Geneva, Available at: <http://www.unepfi.org/publications/property/index.html>

² See: ISO TC 59 SC 17, http://www.iso.org/iso/iso_technical_committee?commid=322621

³ See: CEN TC 350, http://portailgroupe.afnor.fr/public_espacenormalisation/CENTC350/index.html



many leading real estate organisations have some form of “sustainability check” (e.g. based on existing sustainability labels / certificates) in place in order to assess the buildings they wish to invest in and/or to track the performance of their existing portfolios.

At the corporate level, the integration of sustainability aspects follows the tradition of taking responsibility towards society and the environment. Again, the results of standardisation activities at ISO⁴ can serve as a suitable, general guideline for that purpose. The focus is on safeguarding the long-term economic success of a company while avoiding, or at least minimising, the negative impact on society and/or the environment through the organisation’s activities. Within the real estate industry, the development of guidelines and structures for sustainability reporting – notably through the Global Reporting Initiative (GRI) and its Construction and Real Estate Sector Supplement⁵ – has triggered a strong move towards the consideration of sustainability issues at the corporate level.

Overall it can be confirmed that the perception now prevails within the real estate industry that there is a need to act on sustainability issues and that such actions can contribute to increasing reputation, returns and overall corporate success. But even though sustainability is now considered as a corporate success factor, this has not yet led to corporation-wide, concerted actions but to specific and rather isolated application of tools and methods at different hierarchical levels. Therefore, the successful integration of sustainability aspects into the strategic and operative management of real estate organisations requires distinguishing between different hierarchical levels – corporate level, portfolio level, and single building level – and taking targeted actions at each of these levels in order to ensure that sustainability-related data/information flows efficiently within an organisation as well as between an organisation and its external service providers and business partners.

Identifying the problem and resulting challenges

Sustainability has risen rapidly up the business and investment agendas of real estate organisations in recent times. To a certain extent, sustainability is already embedded in many organisations’ mission statement and has become an elusive corporate goal. However, full implementation into all operative management functions and decision-making processes as well as alignment of wider organisational goals with day-to-day-actions remain key challenges. The need to assess and compare the environmental, social and governance (ESG) behaviours in property portfolios is often perceived as a burden and cost factor, or as just another duty within ESG-commitments [1]. This perception and practice had consequences not only for data collection and analysis processes within the industry. Also, from a boardroom perspective the interrelationship between sustainability metrics and real estate investment and asset management operations therefore often remain unclear.

⁴ See: <http://www.iso.org/iso/home/standards/iso26000.htm>

⁵ See: <https://www.globalreporting.org/reporting/sector-guidance/sector-guidance/construction-and-real-estate/Pages/default.aspx>



A recent survey of international property investors and managers revealed that sustainability-related data/information are not yet systematically captured and processed within real estate organisations. See [2]: Some data is lurking in a range of different corporate departments without the facility to share data (silo effect). More than two-thirds of the responding organisations (81%) currently have some form of “sustainability check” in place in order to assess new and/or existing buildings. However, very few organisations (16%) are actually able to utilize this information for sustainability reporting functions. This is because sustainability checks for buildings are mostly carried out in isolation and outside of standard data gathering processes with little or no connectivity to wider corporate frameworks. In addition, there is reliance on analytical tools from third-party service providers (since facility management functions are often outsourced), as well as sustainability assessment results that are already processed (i.e. often highly aggregated). Above all, there is an absence of centralized information databases for building-related data/information. 58% of survey participants responded that they do not have any form of internal information management system in place. This not only hinders the exploitation of the added value of sustainability-related information but also impedes a more profound understanding of the relevance of these data/information for investment and management processes. So there is a potential stalemate situation.

Towards an integrated approach: Corporate Real Estate Sustainability Management

In order to solve the aforementioned problem not a single solution but a solution space is needed. This solution space is comprised of the following elements:

- 1) Analysis of different stakeholders’ information demand in relation to specific success factors within different decision making contexts at different hierarchical levels (i.e. corporate level, portfolio level, single building level).
- 2) A profound explanation and understanding of impact chains. The notion of ‘impact chains’ is used to demonstrate the mutual interrelationships between various levels of building performance and investment level performance. Impact chains can, for example, reveal how technical data on physical and performance aspects can be used to generate valuable information that is relevant for decision-making.
- 3) The mapping of impact chains by corporate information flows. This requires a systematic and holistic approach to data/information across the whole organisation in order to ensure data accessibility and comparability across different corporate departments.

At a practical level, it necessary to consider that information flows need to be structured and managed in relation to three different domains (see Figure 1):

a) Organisational: the sharing and aggregation of information and data across different hierarchical functions and levels within the organisation.

b) *External*: relevant data/information need to flow efficiently between an organisation and its contractors, third-party service providers, stakeholders; as well as between the parties involved in property transactions.

c) *Cross-over*: a property organisation takes the role of an information-sharing platform between its business partners and service providers. It can be a valuable information source, for example for valuation professionals.

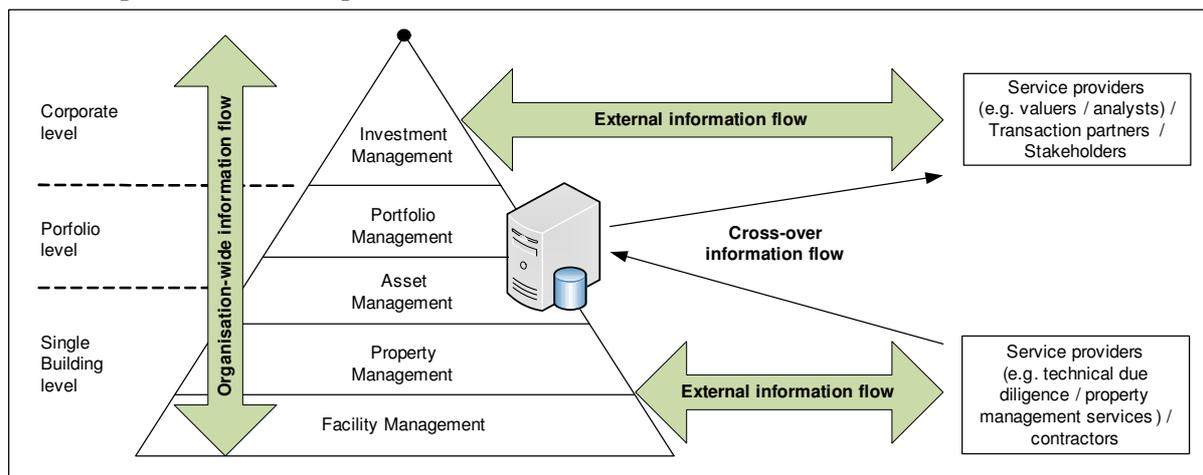


Figure 1: Simplified representation of information management domains

A systematic and holistic approach to data/information is an integral part of Corporate Real Estate Sustainability Management (CRESM) which can be defined as the integrated management of all economic, environmental and social aspects of an organisation’s real estate activities and associated investment decision-making. It involves all relevant strategies, processes and organisational structures that support corporate governance and sustainable business and product development. CRESM requires dealing with an extended information and data basis at all management levels of an organisation.

On the one hand, it is necessary that sustainability-related data/information is collected, organised, and transferred from bottom to top (i.e. from the building level to the corporate / boardroom level) so it can be interpreted and used as a valuable source within different decision-making contexts at different hierarchical levels of an organisation. On the other hand, it is required that targets are set and enforced from the top to the bottom because several requirements regarding the performance and characteristics of buildings / portfolios emerge from a given corporate vision and investment strategy. Or expressed another way: in order to comply with a defined corporate vision and investment strategy, an organisation’s investment properties (and its owner-occupied properties) need to meet (amongst others) environmental and social performance requirements. In order to determine the degree of compliance as well as resulting corrective actions, property performance needs to be measured, monitored and reported. These relationships between a bottom-up flow, transformation and reporting of information/data and a top-down target setting, monitoring and controlling can be further exemplified by referring to selected initiatives and corporate functions, processes and methods. These are shown in Figure 2.

	a	b	c	d	e	f	g	h	i	k
Initiatives & corporate functions / processes (Examples)	UN Global Compact	Principles for responsible Investment (PRI)	Sustainability reporting (Global Reporting Initiative, GRI)	Global Real Estate Sustainability Benchmark (GRESB)	Sustainability in Portfolio Analysis and Management	Sustainability in Market Analysis	Sustainability in Property Valuation	Sustainability assessment of single buildings	Sustainability in Facility Management	Sustainability in planning and acquisition
<i>Corporate level</i>	■ ↓ ↑	■ ↓ ↑	■ ↓ ↑	■ ↓ ↑	■ ↓ ↑		■ ↓ ↑	■ ↓ ↑		
<i>Portfolio level</i>	■ ↓ ↑	■ ↓ ↑	■ ↓ ↑	■ ↓ ↑	■ ↓ ↑	■ ↓ ↑	■ ↓ ↑	■ ↓ ↑		
<i>Single Building level</i>	■ ↓ ↑	■ ↓ ↑	■ ↓ ↑	■ ↓ ↑	■ ↓ ↑	■ ↓ ↑	■ ↓ ↑	■ ↓ ↑	■ ↓ ↑	■ ↓ ↑

Notes: —▶ = Setting of targets and requirements; - - - ▶ = Information flows / reporting functions

Figure 2: Attribution of selected initiatives & corporate functions / processes to different hierarchical levels

Compliance with these initiatives and a successful integration of sustainability considerations into corporate functions / processes requires not only extending the information/data basis but also further developing these processes and methods. Table 1 contains selected recommendations in this regard.

Table 1: Recommendations for selected corporate functions, processes and methods (activities)

Activity	Recommendations for an integration of sustainability aspects / issues
Facility Management	<ul style="list-style-type: none"> • Extend facility management routines by energy consumption monitoring, operating cost controlling, post-occupancy evaluations in combination with complaint management, and tenant satisfaction surveys • Ensure regular reporting (also of third-party service providers) to the asset management / portfolio level
Planning / Design	<ul style="list-style-type: none"> • Embed sustainability targets in the clients brief • Create integral planning/design teams • Carry out sustainability assessment along the planning phase • Make sure that building documentation / building files are issued
Asset acquisition / investment process	<ul style="list-style-type: none"> • Request building-related information and documentation. Treat its absence as a potential deal-breaker. • Integrate sustainability aspects into due-diligence routines • Apply sustainability-quick-checks
Property Valuation	<ul style="list-style-type: none"> • Apply Discounted-Cash-Flow Methodology (if possible); fine-tune DCF-models to establish relationship between an asset's sustainability performance and applied risk premiums, depreciation rates, rental

	<p>growth estimates, exit yields, etc.</p> <ul style="list-style-type: none"> • Link valuation models with Monte Carlo Simulation techniques • Increase the transparency of valuation reports
Portfolio analysis and management	<ul style="list-style-type: none"> • Adopt a three-dimensional approach to portfolio analysis; financial success factors are depicted in relation to the quality characteristics of the individual building as well as its location and market environment. • Extend the factors used to describe quality characteristics by sustainability-related variables
Location and market analysis	<ul style="list-style-type: none"> • Extend analysis to include sustainability aspects such as type and extent of climate change risks, potential for solar energy use, etc. • Undertake efforts to capture the local market participants' preferences and willingness to pay in relation to sustainable buildings

As an example for the further development of corporate functions, processes and methods, a brief discussion of the integration of sustainability aspects into portfolio analysis will be provided below.

Example: Integration of sustainability aspects into portfolio analysis

In general, two different approaches to portfolio analysis are used in practice: One the one hand, quantitative approaches that focus on an analysis of the structure of correlations between the returns of properties or groups of properties in order to minimize the portfolio risk. The foundations of these approaches are based on the well-known findings of Harry M. Markowitz in the 1950s: the higher the number of assets in the portfolio (whose returns are not or at best negatively correlated), the lower the risk of the portfolio (i.e. variance of portfolio return). On the other hand, qualitative approaches based on the adoption and further development of early models developed by Boston Consulting Group (“BCG-matrix”) and McKinsey to the particularities of real estate organisations. Here multi-dimensional scoring models are used to analyse and display the market attractiveness of property assets or groups of assets in relation to the quality characteristics of the building and its location and market environment (see Figure 3).

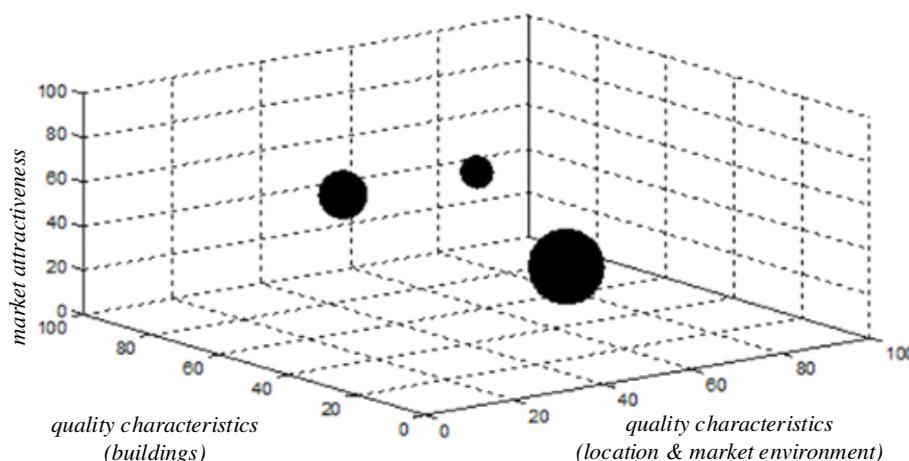


Figure 3: Example for a three-dimensional approach to portfolio analysis
 Notes: Circles represent single buildings; size of the circle indicates the building's market value



Both aforementioned approaches need to be combined because quantitative approaches ignore the qualitative characteristics of buildings and of their location, and qualitative approaches ignore the correlation structure of the assets' returns. As recommended and further explained in [2] traditional as well as sustainability-related variables should be used as factors to describe the characteristics of buildings and their location and market environment. Over time, this approach will allow for more sophisticated analytics enabling a better understanding of the relationship between the sustainability performance of property assets and their overall financial performance.

Sophisticated analytics would need to go further than just analysing sustainability aspects at a highly aggregated level. Instead, analysis needs to be performed by making use of disaggregated, sustainability-related data/information. Therefore, real estate organisations are well advised to store and preserve data/information in disaggregate format. As more and more data accumulates, this allows using sustainability-related information/data (such as energy performance) as independent variables and financial performance measures (e.g. total return, capital growth, net income return) as dependent variables in multiple regression models. This allows the determination of weighting factors for the aggregated portfolio model as well as a more detailed analysis of the effects of location and building characteristics on the financial performance at the single building, portfolio and corporate level. Finally, such an approach would lead to a deeper understanding of what will make property 'future-proofed' in environmental, social and economic terms.

Summary

This paper attempts to highlight the benefits that arise from a more consistent and integrated approach to the management of sustainability-related data/information within real estate organisations. The most obvious benefit is an improved understanding of the impact of sustainability performance on asset and portfolio value. It also enables organisations to understand and assess the impact of sustainability-related activities at the building level on corporate value. Further benefits arise when several corporate functions and methods of property investment and management organisations rely on similar data/information. The additionally gathered (or now accessible) building-related data/information can be utilized several times and in many situations to support business processes and corporate functions (for example: risk management, valuation, sustainability reporting, etc.). This multiplicity of use suggests that the benefits of adopting an integrated approach far outweigh the required implementation efforts.

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A Framework for People Capability Enhancement to Support Sustainable Facility Management Practices

Speakers:

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Abstract: *Spans over a considerable length of time, facility management is a key phase in the development cycle of built assets. Therefore facility managers are in a commanding position to maximise the potential of sustainability through the operation, maintenance and upgrade of built facilities leading to decommission and deconstruction. Sustainability endeavours in facility management practices will not only contribute to reducing energy consumption, waste and running costs, but also help improve organisational productivity, financial returns and community standing of the organisation. At the forefront facing sustainability challenge, facility manager should be empowered with the necessary knowledge and capabilities. However, literature studies show a gap between the current level of awareness and the specific knowledge and necessary skills required to pursue sustainability in the profession. People capability is considered as the key enabler in managing the sustainability agenda as well as being central to the improvement of competency and innovation in an organization. This paper aims to identify the critical factors for enhancing people capabilities in promoting the sustainability agenda in facility management practices. Starting with a total of 60 factors identified through literature review, the authors conducted a questionnaire survey to assess the perceived importance of these factors. The findings reveal 23 critical factors as significantly important. They form the basis of a mechanism framework developed to equip facility managers with the right knowledge, to continue education and training and to develop new mind-sets to enhance the implementation of sustainability measures in FM practices.*

Keywords: *sustainability, people capability, facility management, knowledge*

Introduction

Facility management (FM) faces a significant environmental challenge. The pursuit of sustainability in facility management requires a concerted response from all construction industry stakeholders. As a sector that spans over a considerable length of time, facility management is also a key phase in the development life cycle of built assets. The energy usage for power and maintenance during the operation phase of a built asset alone account for approximately 45%, compared to 5% used during the construction phase (CIOB 2004). These scenarios present increased demand for FM practices to follow ecological friendly processes and consider the long term prosperity and wellbeing of future generations. Furthermore, sustainability facility management practices will not only contribute to reducing energy use, waste and running costs, but also help improve organisational productivity, financial return and community standing of the organisation (Hodges 2005; Nielsen et al. 2009; Lai and Yik 2006).



However, despite the emerging awareness of sustainability in facility management, very few facilities managers and built asset owner voluntarily actively take on the sustainability agenda due to the infancy of sustainability in the FM profession (Elmualim et al. 2008). There is a lack of understanding and skills required to put the sustainability agenda into action (Shah 2007; Elmualim et al. 2008). It is believed that appropriate capabilities and skills among FM practitioners can contribute enormously to the implementation of the sustainability agenda in the FM sector (Hodges 2005; Shah 2007). Yet according to previous studies, FM practitioners suffer from the lack of capabilities and inconsistency of the required skills in this area. Moreover, problems such as the lack of specific sustainability knowledge and new environment friendly products, systems and technology add to the difficulty (Shah 2007; Elmualim et al. 2009; Elmualim et al. 2010). A complete transition to sustainable FM practice will not materialise until facility managers are empowered by the necessary knowledge and capability.

This paper discusses an ongoing research aimed at identifying the critical factors for enhancing enhancing people capabilities and on such basis, to develop a framework of promoting the development of professional capabilities to deliver the sustainability agenda in FM practices. A total of 60 factors were first identified through a comprehensive literature review. A questionnaire survey was then conducted to identify the perceived importance of those factors. A framework is developed to promote the necessity of people capability enhancement and equip facility managers with the right knowledge, encourage them for continuing education and training, and to develop new professional mind-sets. By doing so over time, it is hoped that the work force of facility management can uplift its capability and become better prepared for the implementation of sustainability measures in FM practices.

People Capability to Support Sustainable Facility Management Practices

Because of their long term involvement and ability to make major operational decisions, FM professionals are at the forefront of integrating sustainable practices through work routines. In addition to their technical and operational skills, FM professionals have a great opportunity to make a valuable strategic contribution towards their organisation's sustainable business. However, limited capabilities among professionals in achieving this vision has entered into an alarming situation and solutions were much needed (Shah 2007; Elmualim 2013; Hodges 2005). To start with, the FM professionals need to understand and recognise how the growing importance of sustainability is influencing the way they carry out their duties, roles and responsibilities. FM personnel must become professionally competent and knowledgeable about the sustainability issues that will impact on their business environment, both operationally and strategically (Elmualim 2013).

To establish a theoretical knowledge base and use it to guide through the research and data collection and analysis, a background review of literature was conducted to understand what people capability (PCap) factors are there and how they would impact on the consideration of sustainability measures in facility management practice. This understanding contributed to the establishment of a knowledge underpinning on sustainability related knowledge and skills



required for FM practices. Factors related to people capability in the construction profession were identified from the existing related studies. These factors cover a wide spectrum of issues, such as understanding whole-life value concept, ability to work across disciplines and a vision for a better future. The literature review conducted has also contributed to the development of research methodologies suited for this research project.

Sixty factors were identified through literature as having influence over people capabilities related to pursuing sustainability. They were grouped into five categories based on Wiek et al. (2011)'s classification for a similar application. These include interpersonal capabilities, system thinking capabilities, anticipatory capabilities, normative capabilities and strategy capabilities. In this research context, interpersonal capability relates to enabling FM personnel to solve issues and respond to challenges of sustainability applications. System thinking is about being able to analyse complex systems across three different pillars of sustainability and over different scales. Anticipatory capability will facilitate analysis and evaluation of sustainability actions and consequences. Normative capability is to map, apply and resolve sustainability values and principles in a person that should either be discarded or maintained to sustain the balance of nature. Finally, strategic capability will contribute to specific sustainability implementation strategies in an organisation.

Research Methodology

This research aims to promote the uptake and implementation of sustainability measures in FM practices through identifying the criticality of people capability factors, and use it as the basis for the establishment of a mechanism to equip facility managers with the right knowledge, to continue education and training and to develop new mind-sets. A questionnaire survey was selected as the primary tool to identify the significance of 60 people capability factors revealed by the comprehensive literature review. The accuracy and suitability of the questionnaire questions were validated through 6 pilot surveys with industry practitioners and academics before distribution to the survey correspondents. The questionnaire included 4 parts, namely; 1) Respondents' demography, 2) People capability factors, 3) Further comments, and 4) Invitations to further participate in this research. The respondents were selected among the members of facility management association in Australia and Malaysia including Facilities Management Association of Australia (FMA), Tertiary Education Facilities Management Association (TEFMA) and Malaysian Association of Facilities Management (MAFM). These are leading professional institutions for FM practice in these two countries. During the pilot survey, it was also identified that FM practices in both countries follow very similar procedures with almost no distinctive variation due to cultural or political differences. It is expected that consensus among the respondents will represent the general views of the FM profession.

A total of 134 surveys were distributed using online survey and face-to-face consultation. As a result, 52 valid responses were received and used in the analysis with a response rate of 36%, which is acceptable based on the survey study criteria by Akintoye (2000). It is noted that all respondents played an important role in the FM sector. There are facility managers

(33%), asset and facilities management consultants (25%), company directors (21%), building engineers (15%) and academics (6%). Almost 50% of respondents had over 21 years' experience in the construction industry. Furthermore, 74% of the respondents had been involved in the FM sector for more than 5 years.

Ranking of Critical People Capability Factors

The level of significance of the 60 people capability (PCap) factors was identified through the analysis of the survey data. The mean value of each factor was calculated first. 23 of them were finally selected as critical PCap factors with their mean value ≥ 4.00 ("significant") as shown in Table 2. In addition, the uniformity of the standard deviation (all below 1.0) demonstrates data accuracy and consistency in the research.

Table 2: Ranking of the 23 critical people capability (PCap) factors for enhancing sustainability measures in FM practices

	People capability (PCap) factors	Mean	Std. Dev.	Rank
	Strategic capability	4.14		
S2	Understand the LCC and TCO technique	4.38	.661	1
S10	Understand whole-life value concept	4.31	.643	2
S5	Develop good relationship with the organisation's top management	4.21	.776	4
S1	Understand the organisation's financial strategy	4.19	.742	6
S8	Ability to optimise the building and equipment operations	4.12	.704	11
S3	Understand the design and construction issues related to FM practice	4.08	.682	12
S6	Familiar with the building systems manual	4.06	.752	13
S4	Develop organisation's sustainability strategies	4.04	.656	15
S7	Ability to monitor and maintain equipment efficiency	4.02	.779	20
S9	Ability to specify the energy and environmental goals to associated suppliers and contractors	4.00	.594	21
	Anticipatory capability	4.10		
A3	Take a long-term perspective	4.21	.667	5
A1	Identify short-term and long-term consequences of any decision/plan	4.12	.583	10
A4	Vision for a better future	4.06	.752	14
A2	Identify direct and indirect consequences to people and ecosystems	4.02	.610	19
	Interpersonal capability	4.09		
P6	Ability to work across disciplines	4.25	.711	3
P5	Ability to motivate other stakeholders	4.19	.687	7
P4	Self-motivated	4.17	.678	8
P1	Communication skills	4.02	.754	16
P2	Collaboration skills	4.02	.577	17
P7	Ability to plan and implement sustainability efforts	4.02	.542	18
P3	Courage to make changes	4.00	.792	23
	System thinking capability	4.06		
ST2	Understand the meaning, goal and issues of sustainable development	4.12	.615	9
ST1	Understand the bigger picture of significant aspect of sustainable development	4.00	.741	22

The research findings reveals that the FM practitioners believed the strategic capability

will affect the enhancement of sustainability endeavour the most, with the highest overall mean value of 4.14 among the four micro-categories of key factors. The two top ranked factors, S2 “Understand the LCC and TCO technique” (mean value=4.38) and S10 “Understand the whole-life value concept” (mean value=4.31) are in the Strategic Capability category. This finding supports the existing views that the understanding of LCC and TCO is a driving force of sustainable practice in FM because of the large proportion of operation and maintenance costs in the overall cost of building assets (Fuller 2010; Hodges 2005; Shah 2007). Factors S5 “Develop good relationship with the organisation’s top management” (mean value=4.21) and S1 “Understand the organisation’s financial strategy” (mean value=4.19) was ranked fourth and sixth and thus was also regarded as an important capability since the financial strategy regarding sustainability policy can only be decided by the organisation’s top management (Elmualim 2013; Hodges 2005).

An overall second rank is the Anticipatory Capability category with the overall mean value of 4.10. Factor A3 “Take a long term perspective” (rank 5) and Factor A1 “Identify short term and long term consequences of any decision/plan” (rank 10) are also regarded as highly important ones for sustainability integration in FM practices. It is essential to be able to think beyond the present in order to develop different alternatives of action based on present condition. Through foresighted thinking, the potential opportunities and risks can also be identified.

Followed closely in the third rank is the Interpersonal Capability category with an overall mean rank of 4.09. In terms of individual factors, P6 “Ability to work across discipline” (mean value=4.25) was ranked as the third most significant factors among overall PCap factor. It is also noted that other factors related to interpersonal capability dimension also received a higher ranking. They were ranked as “significant” or “very significant” in the survey, such as P5 “Ability to motivate other stakeholders” and P4 “Self motivated”, with a high mean value of 4.19 and 4.17 respectively. This is consistent with several viewpoints of previous studies (Sexton and Barrett 2003; Sterling and Thomas 2006; Barth et al. 2007), which highlighted that solving sustainability issues and generating sustainability opportunities requires strong collaborations as well as negotiation skills among the stakeholders.

The survey revealed that system thinking capability factors were less viable and were ranked as the least significant factors among all. This may reflect the fact that FM practitioners have realised their roles in supporting the sustainable development agenda (Nielsen et al. 2007). However, the bigger challenge is how to identify the most appropriate approach to attend to sustainability and how FM practitioners can equip themselves with new knowledge, tools and competencies to overcome the challenges. None of the people capability factors categories in normative capability was considered as significant factors in order to enhance the sustainability effort in FM since all of these factors have a mean score less than 4.0.

A Framework for People Capability Enhancement to Support Sustainability in Facility Management Practices

Twenty three factors that significant in supporting sustainability in FM were extracted from the questionnaire survey analysis. To summarise the findings and results of this survey, a three-level hierarchical conceptual framework for people capability enhancement to support sustainable facility management practices was proposed as shown in Figure 1. The top level

is the expected outcome, and following this is the four groups of PCap category. Lastly, the third level comprise the factors expending from the people capability.

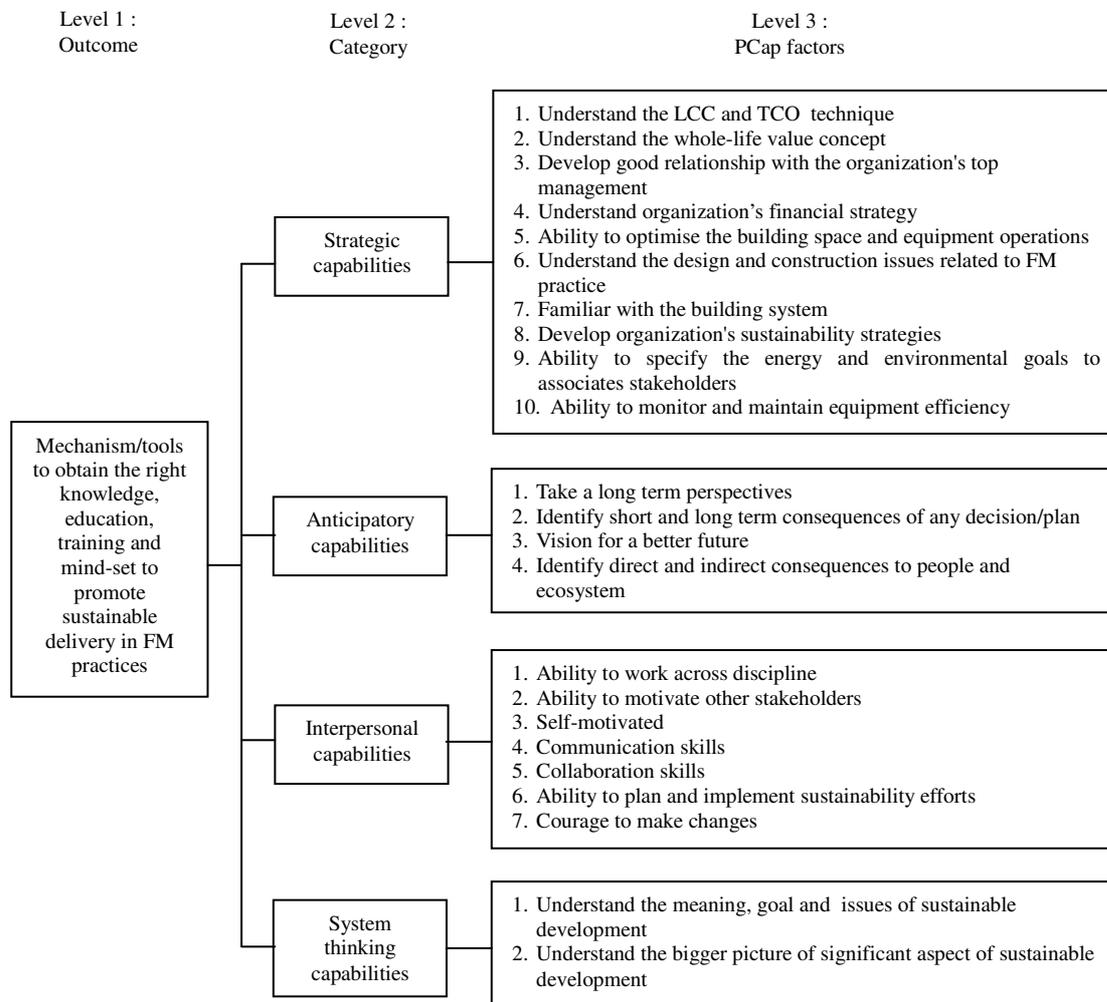


Figure 1: A conceptual framework for people capabilities in promoting sustainability in FM practice

Conclusions

There is an increasing level of awareness to incorporate sustainability principles into facilities management practices. This presents a high pressure for the construction professionals to equip themselves with proper knowledge, skills and capabilities to face the new sustainability challenges. Against such a backdrop, people-centred approaches have a good prospect to assist facility managers. In this study, twenty three critical people capability factors were identified through the questionnaire survey of industry practitioners. They are categorised into 1) Strategic capabilities, 2) Anticipatory capabilities, 3) Interpersonal capabilities and 4) System thinking capabilities. The top ranked factors include “understanding of life cycle costs”, “understanding of whole life value concepts”, “ability to work across disciplines”, “develop good relationship with the organisation's top management” and “take a long-term perspective”. Using an established people capability categorisation, these factors are summarised into a Conceptual People Capability framework to provide guidance to the FM



practitioners to improve their core capabilities. Work is ongoing to further investigate these factors in terms of interdependency and hierarchical significance. A pair-wise comparison study will be used together with Interpretive structural modelling (ISM) to develop a hierarchical model showing the driving forces among all identified factors. A final people capabilities framework will be formulated and case studies will be used to test, improve and validate the framework. These combined efforts will help raise the awareness of the FM practitioners and provide them with a tool to develop new mindset and continue professional development for the implementation of sustainability facility management practices.

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A sustainable? urban planning for the poorest

Speakers:

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Abstract:

One of the building sector's challenge, if they are worried about environment and sustainability, is an overwhelming housing deficit and new urban growth in the least developed countries. Urban planning must pre-date, must be able to anticipate, even spontaneous construction.

Which instruments can be put into practice to avoid and control the urban squatting, dealing with the poorest population's housing demands and reality, favoring the development of human sustainable settlements?

Urban planning, since the 60's, implemented some concrete instruments to control the creation of urban informal settlements, but none of the scale and characteristics of the Guided Occupancy Programme, successfully implemented by the city of Trujillo, Peru, for over a decade. This programme constitutes an exemplary approach to the problem. While not necessarily constituting an universal solution, it might be viewed as a viable and reproducible alternative in situations of widespread poverty as a sustainable urban planning for the poorest.

Keywords: urban planning, basic habitability, urban squatting, guided occupancy

Introduction to the ongoing debate on urban squatting

The world population increases in more than 70 million person per year, and it takes place - according to the urbanization trends of the planet- preferably in the developing countries' cities. Either the building sector nor the urban planning discipline have been capable of attending the problem and its scale.

The urban poor have to solve an equation with diverse variables: the need of access to soil, optimize housing costs, the dwellings quality, access to infrastructures and services, or the displacement to the work. The result is a mixture of high costs, absence of municipal services and insecurity in the property of the soil, and it makes up the slums of the cities in the developing countries, where nowadays a third of its population lives overcrowded, without drinking water nor [improved sanitation](#) or in insecure and unhealthy housings.



Seven of every ten housing units in the world that are auto-built because the formal market does not have capacity of response: the poorest, trying to solve their habitat equation, invade areas where build a shelter.

Urban squatting or “invading” land that belongs to someone else is usually the initial stage of what, over time, become *slums* or *tugurios*, variously termed *callampas* in Chile, *favelas* in Brazil, *limonás* in Guatemala, *ranchos* in Venezuela, *villas miseria* in Argentina, *pueblos jóvenes* in Peru, *ciudades paracaídas* in Mexico or *bidonvilles* in French-speaking countries. Such communities house 23.5 % of the urban population in Latin America (1)

Squatting and slums (the latter defined here as in the United Nations publication (2)) are closely related, for they can be seen as two consecutive periods or stages of the same process: squatting as the starting point, and slums as the long-term result. The ultimate aspiration is to convert such communities into consolidated neighbourhoods in the shortest possible time. Not all slums can trace their origin to squatting, however.

Slums are the result of processes that graphically reveal the absence of urban planning in cities in nearly all developing countries. Squatting is the outcome of the pursuit by the less advantaged, nearly always domestic migrants, of employment and the health and education services lacking in their places of origin (3).

Sustainability and settlements are related, as the Millennium Development Goals show in its 7th goal: to ensure environmental [sustainability](#), when it defines its target 7D: "By 2020, to have achieved a significant improvement in the lives of at least 100 million slum-dwellers". However, they did not take into account, that the slum-dwellers continued growing up, and that as important as improve the lives of those 100 million slum-dwellers, would be implement new and sustainable urban planning policies.

Basic habitability: urban planning for the poorest

According to the Superior Technical School of Architecture of Madrid's Institute for Cooperation in Basic Habitability (ICHaB), *basic habitability* means conditions that “...meet the essential need for shelter common to all human beings. Satisfying that need entails covering residential urgencies, but not as regards habitation alone, but also public space, infrastructure and the elementary services that together constitute a settlement that favours population growth. Basic habitability therefore includes a supply of potable water, wastewater collection, elimination of solid waste, basic social assistance, transport and communications services, low-cost roads, energy, health care and emergency services, schools, public safety, spaces for leisure, seed housing...” (4)

The *basic habitability* process, as all systematic urban development processes, take place in four consecutive, separate but interrelated stages. The last three, *land allotment*, *urbanisation* and the *building process*, are three successive interdependent levels (5). The first stage is perhaps the most important, the most significant in terms of the wider results of the urbanisation process. This stage, *appropriate site selection*, or to be more precise, the *suitable*



selection of the right urban area, will guarantee that the next three stages are successful and have lasting effects (6).

Of course, such a systematic process of urbanisation has a theoretical foundation that is not always present in real situations. Indeed, historically, until urban development became a discipline in and of itself in the decade straddling the 19th and 20th centuries, cities developed quite spontaneously, in a way that was very different from this systematic, four-stage urban process. Today this is no longer the case, and at least in the developed world, laws dictate—not always explicitly, but tacitly—that human settlements be built according to these four stages that control urbanisation to varying degrees: first, land that is adequate for the use it will be given is selected; second, land is divided into private plots and a network of public spaces; third, this network is developed; and fourth, building occurs, with private housing representing the majority of construction, along with public facilities and services and other activities that may be either public or private.

However, in informal urbanisation (7)—a process that guides the majority of human settlements in developing countries and is still present in some regions of the developed world, in the so-called Fourth World—this spontaneous growth prevails. Vulnerable and unsuitable land is occupied, or land allotment is inadequate or not properly planned according to precise measurements, which means that the development of a network of public spaces, which has not been clearly allotted, never occurs, and that the building process is limited to the very precarious construction of so-called *housing solutions* that the settlers, with their limited economic and technical capacities, are able to build themselves. This results in a situation of *precarious habitability*.

Improving the results of this precarious habitability and moving as much as possible towards *basic habitability* depends on systemising spontaneous urbanisation according to these four structured stages. This systemisation must be implemented to remedy cases of precarious living conditions in general. Obviously, the presence and intervention of the public sector facilitates systematisation according to the four stages discussed above, which means greater technical capacities and better organisation, determining factors in achieving optimal results in the urbanisation process.

On the other hand, considering the fact that poor settlers build their inadequate housing themselves because their lack of economic resources means their housing needs cannot be met in the official, formal market, and that the public sector does not generally participate in this informal urbanisation by carrying out the role that the more systemised process lays out for it (the selection of adequate land, subdivision of plots and development), the public sphere should at least facilitate the real process of informal urban growth. This can be done through the legalisation of this *de facto* situation, the realistic adaptation of urban land use regulations and the rationalisation, as far as possible, of the human settlement process; and particularly through the adequate selection of residential land, rationalised land plots and the development



of infrastructures and public services, leaving the building process to the settlers themselves, who would receive technical and economic assistance from the public sector.

Hence, we consider poor populations' spontaneous manner of constructing residential settlements to be an appropriate, ongoing demonstration of what the poor are willing to do to overcome poverty. Their self-build processes and how they organise themselves are factors that need to be taken into account, and will become much more efficient once the process is systematised and the public sphere carries out its function of providing technical guidance and economic support. In building their informal settlements, the poor have specific ways of organising themselves, relying on self help and mutual aid, saving and buying materials and applying building techniques. We need to harness and fine tune these methods in order to achieve more efficiency in basic habitability processes.

This proposal is simply a practical expression of what is often called an *enabling strategy* for these spontaneous urbanisation processes. It involves taking a realistic approach to institutionalising informal urbanisation to improve the outcomes of different types of marginal human settlements.

Non-conventional housing policies

Present policy increasingly leans toward the acknowledgement and consolidation of informal settlements (8). The **slum upgrading** is one of the most active housing policies today and one to which sizeable resources are being allocated. This would help to explain that, except where located in vulnerable areas, the results of squatting are more a solution than a problem in response to “housing hunger” (9). Some countries have developed diverse programs of “regularization” of illegal occupations of lands, following the schemas of Hernando de Soto (10). The system might be questioned in itself, the focus limited of those politics “healing”, that promote and they stimulate the informal growth and to increase the problem to the “feedback” the urban informality (11). These would be, therefore, “palliative” policies that address the existing housing problems. A more desirable solution would be to deploy forward-looking, “preventive” policies that anticipate slum creation or at least seek solutions that will not compromise the future of these settlements.

Ex-novo **sites and services** programmes represent the organised and public-sector-driven alternative to the urban squatting as “preventive” policies. The institutional, extended use of sites and services solutions can be said to have begun in the 1960s and peaked in the 70s. The new World Bank philosophy, which was influenced by the ideas of the English architect John Turner, stressed a “sites and services” (provision of basic “wet” infrastructure and civil engineering) approach to help rationalize and upgrade self-help housing. The state became an “enabler” of the poor, although in terms of need, the implemented schemes were a mere drop in the bucket (12).

In practice, a *sites and services scheme* involves handing over a single-family plot with an equipped sanitary core which consists of a kitchen and a bathroom (between 5 and 16 m²) and



is connected to the settlement's general infrastructure. The settlement itself is set up in an appropriate location according to previous ordinances and plot division, as described above.

In our opinion, there are many intrinsic aspects working against the approach. To oversimplify these aspects, we might say that the sites and services strategy is based on actions with little visibility and little opportunity for glamorous home dedication ceremonies. The solutions are intrinsically unfinished and involve a lengthy work period (two years of site resolution-allocation, and a lifetime of work to provide adequate housing). These programmes are sometimes rejected even by people who have nothing because they dream of other types of solutions that hand them the keys to “free, finished housing units”—solutions that will never arrive. The Guided Occupation will have the same problem.

The Alto Trujillo Guided Occupation programme in Peru

The Guided Occupancy Programme described in this section is a municipal scheme that the authors believe merits acknowledgement and dissemination, in light of its practical contribution to citizens' right to basic habitability which ensures them land at least apt for human habitation and future development.

Trujillo, a city on the northern coast of Peru and capital of the Department of La Libertad, stands on the right bank of the River Moche, just a few kilometres inland from the Pacific Ocean (13). In its Metropolitan Plan for Trujillo 2010, which preceded the launch of the Guided Occupancy Programme, the city expressed its alarm over the growth of informal and unplanned urban development in the area and its expected magnification. Inherent in the problem was the insufficient urban development of human settlements due to the high social and economic cost of intervention, which also met with other difficulties such as the uncertainty around land ownership and the scant accessibility of basic services. Squatters were observed to usually choose the wrong areas, areas that might be vulnerable, earmarked for intensive farming or protected as natural or landscape reserves (14).

The high demand for housing generated by the less advantaged part of the population, accentuated by heavy migration flows from the department's inland areas and other regions in northern Peru, was going unmet in Trujillo. The scant supply of housing for this population and the lack of sufficient economic resources to meet demand at the local level intensified urban squatting. Municipal planners therefore established strategies to anticipate the growth of slums on the outskirts of the city, characterised at the time by a total lack of planning and limited or nil access to infrastructure and services. These strategies had at the same time to be compatible with the shortcomings with which local government had to deal. The response was the implementation of a municipal Guided Occupancy Programme (15) (see Image 1).

The programme, largely propelled by architect Amemiya, was launched primarily to halt the spontaneous installation of slums in unsuitable areas and hence to favour the orderly growth of human settlements. The specific objectives included reducing the degree of informal housing, providing readier access to urban land, promoting the rational use of land for urban

purposes (increasing density to raise efficiency), ensuring access to basic municipal services and facilities in the shortest possible time, and furthering co-management by encouraging citizens' and local organisations' participation in urban development planning, management and control.



Image 1. Aerial photo of Alto Trujillo showing the urban structure around which the settlement is organised. From 1995 to 2006, 14 neighbourhoods were progressively occupied. Source: Google Earth photograph, 2006

The programme was implemented in an área known as Alto Trujillo, in the district of El Porvenir, whose location just 7 kilometres from the centre of the city guaranteed accessibility and connectivity. Although characterised by certain limitations, it was chosen in light of the limited availability of other residential land, and special measures were adopted to ensure building stability and occupant safety (restricted occupancy on grades of over 10 %, a ban on buildings of over two storeys without a geotechnical survey and a requirement to build over continuous foundations).

Time has shown that urban planning prior to occupancy and urban growth, in which land was set aside for facilities and services, guaranteed efficiency, reduced costs and waiting periods for access to municipal services and facilities (16). Zoning was primarily residential, but allowed for productive activities in the form of mixed home-workshops to accommodate small-scale productive and industrial activities. The land set aside for parks was sited in areas at risk of flooding.

The basic unit in the model, then, was the neighbourhood, a group of around 800 families occupying some 20 hectares (see Image 2). The programme, in pursuit of greater land use efficiency, allocated 58 % of the total area for private use, 30 % for roads and the remaining 12 % for facilities. Density was 200-250 inhabitants per hectare, greater than the average for the area, to minimise infrastructure costs, while the mean plot size was 140 m². Larger plots, measuring 300 m², were allowed where housing was also used for running a business (home-workshop).



Image 2. Alto Trujillo district planning map, clearly showing the neighbourhood-based urban modulation that informs land management, as well as the technical handling of basic municipal service projects (17)

The success of the Guided Occupancy Programme depended on guaranteeing plot occupancy, in addition to providing access to the land. For that reason, plot ownership was made subject to living permanently in the neighbourhood and committing to take part in its consolidation, which included building a home. The indispensable requirements to qualify for access to the programme was to be registered as a resident, constitute a family unit and not own any other land. Once plots were awarded to eligible families, the population was organised to build priority structures, stake out the plots, condition roads, build latrines and dig wells. Families settled precariously on what were initially “their” plots, with no need to pay for the land, but committing to live on it (otherwise, the land was awarded to another family under the provisions of the Abandoned Plot Reversion Act). From that moment on, the neighbourhood and its homes gradually developed. Title to the property was delivered after a one- to three-year monitoring and assessment procedure. Thereafter, in a process whose duration depended on each family’s economy and the financial contribution available from the city government at any given time, infrastructure was laid and housing and facilities were built (Images 3 to 6).

From 1995 to 2006, 14 neighbourhoods, now home more than 50 000 people, were gradually occupied. In Trujillo, guided occupancy, as a model for gradually fitting occupied land with facilities, became a feasible land management strategy able to fuel urban development in the settlements. The resumption of squatting in 2006 when the programme was discontinued in the wake of a change in the municipal government (See Image 7) stands as proof that it achieved its objectives.



Image 3. Plot stake-out after award to eligible families with “sufficient merits”, under the city’s technical counsel. Source: photograph by Trujillo municipal authorities (PLANDEMETRU)

Image 4. Precarious occupancy of plots, the first step in the gradual improvement process that advances at a pace dependent upon economic resources, but with the certainty afforded by families’ title to the land. Source: photograph by Trujillo municipal authorities (PLANDEMETRU)



Image 5. Replacement over time of the precarious housing built in the first stage by “sound” housing and installation by the city of municipal services such as lighting, wastewater collection and running water. Source: photograph by B. Gesto, November 2012

Image 6. Alto Trujillo residents enhancing their own housing. Source: photograph by B. Gesto, October 2010

Guided Occupancy: a sustainable urban planning?

The value of the Guided Occupancy Programme implemented in Alto Trujillo, Peru, lies in its ability to anticipate the solution that the squatters themselves would otherwise adopt (18).

The four stages of the *basic habitability* process can be readily identified in the practical implementation of the Guided Occupancy Programme. The first stage, the *choice of the site*, was wisely undertaken by the city government. Bearing in mind connectivity, the new district was sited just 7 kilometres from the centre of Trujillo to guarantee future dwellers access to their places of work. At the same time, measures were taken to mitigate site limitations. By not allowing land to be spontaneously chosen, the city ensured settlement on suitable soil where the likelihood of natural catastrophes such as flooding was low (20).



The city also assumed responsibility for the second stage: *rational plot division*. It determined the size of the plots to control densities and reserve public space for facilities, parks and roads, while affording legal certainty in the form of property titles. The city of Trujillo in fact handles and controls the first three stages - stages that lie outside the scope of the community- for it also attends to the *most basic and indispensable urban planning*, in a clear commitment to public over private management. It nonetheless leaves gradual or “incremental” housing construction in the hands of the dwellers themselves.

The question posed is whether the Guided Occupancy Programme can be regarded as a generally applicable solution to one of the most pressing problems confronting humanity: an overwhelming housing deficit and new urban growth in the least developed countries.

As an instrument that covers the entire process in a context in which the population is expected to grow by 25 % (from 800 000 to 1 000 000), the programme is deemed to be a suitable model on a scale able to deal with the squatting problem. But there are three conditions that must be met for its reproducibility in other places: the existence of available *land*, a context of clear growth in the demand for unskilled labour and a *local government* with competence and determination to confront the squatting problem.

However, there is another important topic: single family housing units versus density. In this context, the aim to increase density did not clash with the single family housing unit. The single family dwelling is not merely traditional: it is in keeping with the socio-economic realities prevailing in the area. Collective housing was not feasible in this context, for it would have entailed foregoing self-building and called for larger family investments, which neither the families concerned nor the city could afford. But indeed, as we can see in the images above, the density process happens (Images 5 and 6), and probably, they reach higher densities than the "sustainable" cities of developed countries.

By way of conclusion

Urban squatting continues all over the world, especially in Africa, and comparing spontaneous settlement resulting from unplanned invasion to the outcome of a municipal programme such as Guided Occupancy (21) reveals visible differences, inasmuch as the latter:

- guarantees land ownership, which is transferred from the city to the new dwellers;
- involves rational land selection and plot division that does not compromise families' future, for any subsequent intervention for improvement or growth will be less expensive, easier and faster than in unplanned squatting;
- reserves public space that would otherwise be impossible to provide, and favours subsequent installation of infrastructure;



- hence, guarantee access to better living conditions in a reasonably short period of time.

As a strategy for access to land and urban development, municipal guided occupancy programmes may be a feasible, reproducible and urgent alternative to squatting, providing for comprehensive and sustainable land development in lieu of what Matos Mar (22) describes as “population overflow” and urban growth under conditions of poverty. Guided occupancy programmes such as Trujillo’s may prove to be exemplary if they address the housing needs of the future population in the framework of basic habitability, subject to certain conditions such as local government leadership, land availability for urban expansion and residents’ participation in the process (23).

Viewed from the sound fundamentals afforded by the large scale of their implementation, these schemes may be expected to operate well when the city in question is willing to assume at least the first two stages of *basic habitability* (*choice of soil apt for human habitation and rational plot division*). These two stages, while not involving a particularly large investment, ensure that the future of the settlement will not be compromised, but can expect to acquire access to the economic support needed to continue to progress toward the attainment of decent housing.

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Session 104:

Which are the keys to integrate sustainability in architecture projects?

Chairperson:

Colin, Brigitte

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The Discussion on the Localization Architecture Design Principles of the Project Kaohsiung Houses with Sustainable Perspectives

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Abstract: *According to statistical analysis by WHO, at least 0.25 million people died from natural disasters during the period of January-November 2010. Such a great loss of life could be the result of Global Population Increase and the consequent increase of Energy Resource Demands and Greenhouse Gas Emissions, which cause Global Warming and Environmental Impacts on Mankind's Living Spaces. Therefore, such issues as Mitigation of Dramatic Climate Changes and Enhancement of Carbon Emission Reduction have become major challenges for the development strategies of enterprises, industries, regions and nations. Due to the tropical monsoon climate of Kaohsiung, which is located just south of the Tropic of Cancer, Kaohsiung City Government initiated Project Kaohsiung Houses in 2012; by referring to the case studies of sustainably built environments in different countries, Three Cores, Four Indicators and Ten Key Design Principles, including Pervious Base, Deep Sunshade, Green Roof, Environmentally Friendly Building Materials and Sufficient Ventilation Design, have been developed for the accomplishment of Low Carbon Emission, Localization Identity, Healthy Living and International Sustainable Architectural Characteristics of the Project Kaohsiung Houses.*

Keywords: *Kaohsiung Houses, sustainable, ventilation design, Kaohsiung LOHAS building*

1.Introduction

In recent years, scarcity of global environment resources, and the global climate changes make sustainable development become a global concern. According to the statistics by the World Health Organization (WHO), 250,000 persons died from natural disasters during January-November 30, 2010. Such a great of loss of life could be a result of global population increase, consequent increase of energy resource demands and greenhouse gas emissions, which causes rise of air temperature and the sea level and climate warming and change. As a result, global accidents occur frequently. The CO₂ concentration observed by the National Oceanic and Atmospheric Administration (NOAA) in May 2013 exceeded 400ppm. Heat wave and sunstroke occur frequently around the world. Therefore, such issues as mitigation of



dramatic climate changes and enhancement of carbon emission reduction have become major challenges for the development strategies of enterprises, industries, regions and nations.

Taiwan is located just south of the Tropic of Cancer. It is subtropical and has hot and humid climate. Located in the south of Taiwan, Kaohsiung is a municipality directly under the central government, with an area of 2946km², elevation difference of 3500 meters, and total population of 2.77 million. It has diversified landforms, ethnic group and culture. It has adequate sunshine throughout one year, and is very hot. Kaohsiung has the longest sunshine duration a day in Taiwan. Due to different architectural landscape and life patterns, in consideration of sustainable development, it is more difficult to design suitable local buildings as per one building design code.

In order to design localized buildings in Kaohsiung City, Kaohsiung City Government initiated the “Kaohsiung Houses” in 2012; by referring to the case studies of sustainably built environments in different countries, such as Japanese environmentally symbiotic houses, North European Eco-village, Taiwan Yilan Houses and Taijiang Houses, and SBTOOL, CASBEE, LEED and sustainable building evaluation indicators, three cores “environment sustainability”, “reflection of localization identity” and “healthy living” were formulated after analysis of population, culture, landform, industry and climate, and then ten design principles were extended to establish certification for architecture localization of Kaohsiung Houses and solve residential environment problems caused by hot and humid climate in Kaohsiung. Due to growing demand for building sustainability and the trend, this study initiated the all sectors of society to rethink and position the land environment, copying with global environment change, disaster mitigation, creation of building environment with culture identity, and intended to fulfill low carbon emission, localization identity, healthy living environment, and international sustainable architectural characteristics of the Project Kaohsiung Houses.

2.Literature Review

The current development and origin of sustainably built environments in different countries were summarized by referring to the case studies of sustainably built environments in different countries, such as Japanese environmentally symbiotic houses, North European Eco-village, Taiwan Yilan Houses and Taijiang Houses, SBTOOL, CASBEE, LEED and sustainable building assessment indicators. Next, by review of the existing buildings in Kaohsiung, the design codes for Japanese environmentally symbiotic houses were discussed and formulated.

2.1 Japanese environmentally symbiotic houses

Japanese environmentally symbiotic houses are symbiosis with the environment. Especially, the houses focus on the three issues safe global environment, comfortable and healthy living environment and affine surrounding environment. In the construction plan, further management is conducted for processing and dismantling of components and materials, which are considered in the building planning and design, and cultural life of residents is integrated with housing to form a common mechanism for society and nature. Based on this mechanism,



utilization and protection of the regional facilities are combined with the existing environment and use behaviors, and based on the local materials and life cycle of the existing houses, the design methods and principles can be proposed which can prevent typhoon, rain, salt damage and termite and provide ventilation. Due to the planning contents, design methods and project characteristics, the environmentally symbiotic houses may have different house patterns. In order to build environmentally symbiotic houses, evaluation criteria are prepared to achieve acceptance standard for environment symbiosis, and the general plan indexes are determined according to global environmental integrity, surrounding environment affinity and healthy and comfortable residential environment. The indicators include ten operation methods: energy consumption reduction and effective utilization, utilization of natural energy, waste reduction, protection of ozone sphere, regional ecological diversity and ecological cycle, external and internal correlation, high comfort degree of houses, safe and healthy houses and completion of many congregate dwellings.(1)(2)

2.2 Eco-villages in Scandinavia

With the rise of sustainable development concept, sustainable place, eco-city, green-city, local sustainability, green building and ecological engineering have also been proposed. However, these concepts have too wide scope, and some concepts are only applied to urban areas which are not very useful for small regions or rural regions. In recent years, scholars suggest eco-village concept. Gilman proposed a widely accepted definition in the eco-village report "Eco-villages and Sustainable Communities for the 21st Century" in October 1995, in which eco-villages are defined as "a human scale and full featured settlement, in which human activities are harmlessly integrated into the natural world, in a way that is supportive of healthy human development, and can be continued into the indefinite future". In terms of the above literature, the operation principles can be outlined, including nine dimensions: land area and population, ideas, land planning, living environment, resource utilization, transportation, eco-environment, community development, economy and industry. The eco-village planning and design shall suit the local conditions. Different environment resources, culture and customs for the livable life pattern and contents can be borrowed. Based on the research by Varis Bokalders, they can be divided into three styles: Germany, Holland and Scandinavia. The eco-villages are generally called eco-communities in Northern European countries, and are built and developed with the funds raised by the people who have high environmental consciousness and are actively involved into it. The eco-village pattern is subject to the household layout and population, and demand planning. Also, the focus is on communities are harmlessly integrated into natural environment, and are often built in the suburban areas. (3)

2.3 Taiwan Taijiang Houses

The Tainan City Government initiated the Project Taijiang Houses in planning of the surrounding special zone of Taijiang National Park and the urban planning to shape Taijiang architectural style and highlight Taijiang environmental landscape and features. This project mainly collects existing distinctive buildings types, define the local building languages

in the salt region and provide incentives for planning design of Taijiang houses. The Taijiang houses are classified in terms of type, layout and color system or materials. For the type, Taijiang have above-ground buildings or high buildings on water. These buildings are low rise, consisting of lower north-facing pitched roofs and northeast walls, longer and low rooftops and higher south-facing walls and roofs. The horizontal layout is more than vertical layout. The louvers and eaves can block solar radiation; for the layout, they are unit and complex buildings, and construction of large single buildings is prevented. The principles are that fewer buildings are independently arranged in an open area, and buildings are clustered to prevent uniform distribution; for color or material, the colorfulness is lower, and the colors include gray, greyish white, gray black, grayish brown and brick color; the roofs are gray black, grayish brown or brick color which metal shall be reduced as possible, or dust prevention shall be enhanced. Design principles of Taijiang houses are based on green building design indicators. The design is suitable for Taijiang design principles.(4)

2.4 Taiwan Yilan Houses

As the social modernization develops, traditional Yilan buildings are gradually disappearing. Yilan County Government and Youngsun Culture & Education Foundation initiated Yilan Houses Program and now have completed 16 Yilan houses. It is hoped to provide reference for the county people to build houses. The “Yilan Houses Promotion Plan” can arouse attention of people for quality of living environment and local architectural culture. Yilan houses have six features: “site must be located in Yilan”, “con-design by house owners and architects”, “suit local climate conditions and landscape”, “definitely not imitate urban popular architectural styles”, and “instead of urban house design, pay attention to local design which considers humid and rainy climate and frequent typhoons”, and “Yilan houses suit local natural conditions and social customs. Design of the Yilan houses have 11 principles: supportive site response, high level of environmental consciousness, integration with local vegetation planning, simple pitched roofs with clear priorities, natural and simple local building materials, rich semi-opened space, vegetation, outdoor life space, suitable sequence, life-centered indoor space, typhoon-resistant windows, double walls and exposed pipelines.(5)

2.5 Main international evaluation tools

Since 1990, the evaluation tools have been accepted in international building market as more attention is paid to environmental issues, sustainable design and high performance buildings; due to climate change and environmental deterioration, the evaluation of green performance of the past buildings has been shifted to “overall environmental performance of buildings”. Namely, single buildings have a great impact on planning, design and maintenance of community facilities (Raymond, 2005). In 2008, the World SB08 Conference was held in Melbourne, and discussed global CO₂ emission, warming, energy, building environment evaluation, urban environment microclimate, indoor environment quality, green buildings and etc. Thus, this study collected main evaluation tools mentioned in the conferences, including global SBTool, LEED, CASBEE and nine indicators of EEWB, and discussed assessment

contents and items such as urban environment, building site environment and greening. The CASBEE by Japan has evaluation systems for scale and building types, which are divided into housing scale, building scale, urban scale, and city scale. Moreover, consideration of global warming has been incorporated into CASBEE-NC, CASBEE-UD, CASBEE-UA+B and CASBEE-HI in response to warming and urban tropical island effect. This reveals Japan attaches importance to environmental climate change, especially urban microclimate, ecosystem and environmental greening of building space.(6)(7)

3. Research Design

This study is divided into three phases. First, it discusses general design, design core, and design indicators for architecture localization of Kaohsiung houses through expert symposium. Next, it formulates the preliminary design principles after comparative analysis of the relevant literature. Following that, expert symposium is held three times to formulate operating mechanism of design principles for architecture localization of Kaohsiung houses.

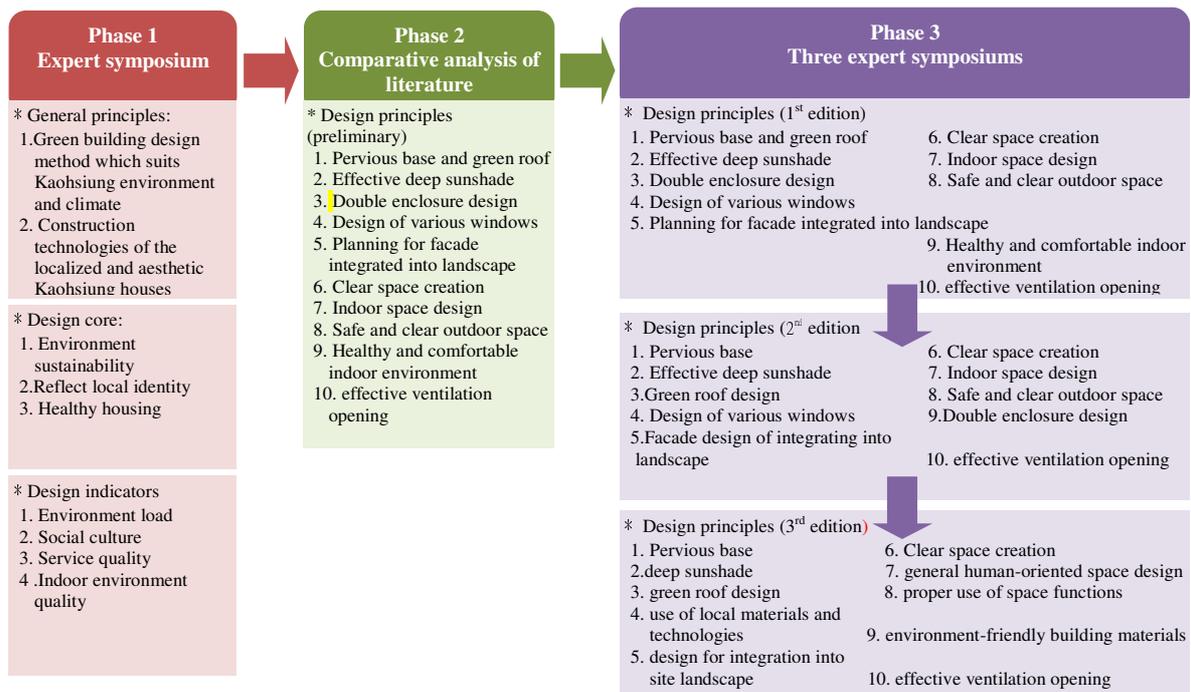


Figure 1 Three phases of research

Phase 1 expert symposium: the expert symposium on August 30, 2012 invited industrial, governmental and academic experts to participate into the discussion. The general design principles (green building design method which suits Kaohsiung environment and climate, and construction technologies of the localized and aesthetic Kaohsiung houses), design core (environmental sustainability, reflection of local identity and healthy housing) and design indicators (environment load, social culture, service quality and indoor environment quality) for architecture localization of Kaohsiung houses are concluded after discussion.

Phase 2 literature comparative analysis: by referring to the case studies of sustainably built environments in different countries, such as Japanese environmentally symbiotic houses,



North European Eco-village, Taiwan Yilan Houses and Taijiang Houses, and SBTOOL, CASBEE, LEED and other sustainable building assessment indicators, the relevant design methods and directions are incorporated. After comparative analysis, the preliminary design principles are formulated, as shown in Table 1.

Phase 3 expert symposium: the preliminary design principles are discussed in the three expert symposiums on September 21, 2012, October 8, 2012 and October 11, 2012 where industrial, governmental and academic experts were invited to participate. After discussion among the participants, the design principles (pervious base, deep sunshade, green roof design, use of local materials and technologies, design for integration into site landscape, clear space design, general human-oriented space design, proper use of space functions, environment-friendly building materials, and effective ventilation opening) for architecture localization of Kaohsiung houses, and approved operation manual and draft on labeling certification for Kaohsiung houses are finally formulated.

Table 1 Comparative analysis of literature

Case	Design direction	Case studies of sustainably built environments in different countries				Sustainable building assessment indicators		
		Japanese environmentally symbiotic houses	North European Eco-village	Yilan Houses	Taijiang Houses	SBTool	LEED	CASBEE
1	Pervious base and green roof	•	•	•				
2	Effective deep sunshade	•		•	•		•	
3	Double enclosure design	•	•	•			•	
4	Design of various windows	•	•	•	•	•	•	
5	Planning for facade integrated into landscape	•	•	•	•	•	•	
6	Clear space creation			•				
7	Indoor space design	•						
8	Safe and clear outdoor space	•	•			•	•	
9	Healthy and comfortable indoor environment	•	•	•		•	•	
10	Effective ventilation opening	•	•	•	•	•	•	

4. Results Analysis

After the above discussion, the design criteria and design methods are formulated, as shown in Table 2. The design criteria for architecture localization of Kaohsiung houses have three cores: “environment sustainability”, “reflection of localization identity” and “healthy living”, four design indicators: “environmental load”, “social culture”, “service quality”, and “indoor environment quality”, and 10 design criteria and contents, as shown in Table 3.(8)(9)(10)

Table 2 Design method for architecture localization of Kaohsiung houses

Design criteria	(Item) Design method
Pervious base	(1) Design for pervious base ; (2) Ground design with water conservation purpose; (3) Flood-control base design
Deep sunshade	(4) Design for eaves of windows or entrance; (5) Design for sunshade windows ;(6)Design for sunshade balcony
Green roof design	(7) Green roof design ; (8) Solar panel roof design ; (9) Environment-friendly insulation roof design
Use of local materials and technologies	(10) Use of local materials; (11) Use of traditional method ; (12) Combination of traditional technologies with modern technologies
Design for integration into site landscape	(13) Building localized environment ; (14)Traditional architectural modeling; (15)Design integrated into environment
Clear space design	(16) Interactive balcony; (17) Daylight ventilated courtyard; (18)Terrace with landscape views
General human-oriented space design	(19) Friendly user facilities ; (20) Clear flow path ;(21)Intelligent indoor facilities
Proper use of space functions	(22) Design for suitably scaled space ; (23) Comfortable and functional place;(24) Simple site layout
Environment-friendly building materials	(25) Natural building materials ;(26) Use of building materials with environment protection label;(27) Use of building materials with green label
Effective ventilation opening	(28) Design for ventilation openings ;(29) Air layer openings for guiding heat flow ; (30)Openings for buoyancy driven ventilation



5. Conclusion and Suggestions

After confirming direction for the design criteria based on the research contents in the expert symposium, the design methods for architecture localization of Kaohsiung houses were proposed by review of the relevant literature and consultation with experts. These methods can solve the living environment problems caused by high temperature and high humidity in Kaohsiung city, conform to the sustainability trend, and help accomplish low carbon emission, healthy living and international sustainable architectural characteristics and localization identity of the Project Kaohsiung Houses. It is suggested that more cases will be investigated in comparative analysis and verification and be distinguished based on different landform features, so as to suit the different landforms in Kaohsiung city.

Table 3 Design criteria for architecture localization of Kaohsiung houses

Core concept	Design indicators	Ten design criteria	Contents
Environmental sustainability	Environmental load indicators	Pervious base	Lawn and permeable pavement is designed between buildings and land.
		Deep sunshade	Eaves or sunshade or balcony are arranged at the different directions of four zones and reflect the performance, and they have cooling effect, and highlight features of Kaohsiung climatic environment.
		Green roof design	Integrate roofs of Kaohsiung houses into natural and ecological landscape, in combination with the open evacuation platform which can indirectly reduce heat load.
Reflection of localization identity	Social culture indicators	Use of local materials and technologies	History and regional features of Kaohsiung city are the direct narrative form. Materials and technologies can be used to show design languages, and make users be closer to buildings.
		Design for integration into site landscape	Different geographical fields have different dialogues. The unique relationship and local taste can reflect the imagery environment identity through internal and external harmony of site.
Healthy living	Service quality	Clear space design	Different settlement styles and features of Kaohsiung city are derived from multi-ethnic culture, and the common venues for gathering Holo, Hakkas and aboriginal people are essential symbol of local culture. Thus, courtyards, terraces and balconies can be used for reinterpretation.
		General human-oriented space design	UD can make each spatial environment suitable for people of various ages and with different physical and mental functions, and each person can use them freely and comfortably.
	Indoor environment quality indicators	Proper use of space functions	Start with space functions of users and find suitable amount of used space. Prevent unnecessary space, and create more comfortable environment for diversified, harmonious and interactive life.
Environment-friendly building materials		On average, people spend about 90% of their time indoor. Thus healthy living space is necessary. Thus, high-quality living environment is based on environmental health concept.	
		Effective ventilation opening	The ventilation openings are designed for air circulation and ventilation so as to reduce indoor CO ² and regulate indoor air temperature and humidity.

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Architectural Approaches to Sustainable Design: Towards an Expanded Definition of Sustainability in the Context of Sustainable Building Transformation

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Abstract: The sustainable transformation of existing buildings is an urgent global concern yet the precise meaning or measure of sustainability in this context is poorly understood across disciplines. Should any change that keeps a building in use be called “sustainable”? Aside from using less energy and fewer resources than a new building, there are important considerations that relate to social and architectural criteria. This paper draws on examples from the Danish context, in particular approaches to the sustainable transformation of modern housing, to argue that attitudes to sustainability need to be more specific to the potential of the building. A transformation should enrich the architecture of the existing building and allow it to fulfil its potential rather than measuring against an ideal. Current sustainable transformation approaches need to be enriched with architecturally focused criteria to allow a more complete perspective of sustainability in relation to transformation.

Sustainability, Transformation, Modernism, Architecture

Background: Modern Housing in Europe

In Europe, between 1966-1975, more housing was built per year than ever before (1). An urgent housing shortage after the war created conditions for government and industry initiatives to build quickly, cheaply and to house as many people as possible. Modern family dwellings took new forms as new housing types were experimented with in the spirit of Modernism. There were not enough skilled labourers to carry out the typical housing construction and together with advances in post-war building technologies these conditions allowed architects seized the opportunity to build new forms. Prefabricated concrete construction became widely used in industrialized building methods for housing.

For example in the Danish context, not only were these dwellings experimental in material and form, but also in their social and political contexts and their suburban contexts. Government benchmarks and planning modifications encouraged a massive social housing projects decade (1). Danish architects played an important role in the development of the Welfare State’s housing policy, expanding their role to include the design of social environments and the space between buildings. The new social housing aimed to provide a democratic infrastructure of housing, giving people modern, safe, convenient, new, uncrowded and well-located dwellings away from the noise and distraction of city centers. Industrialized building methods were strongly encouraged with government incentives. (1) Like most of the social housing in Europe at this time it followed the Modernist concepts (2) of appealing broadly to “users”, generalized climates and anonymous contexts rather than



catering to particular needs. Repetition of elements, monotonous site planning, unadorned building expression, were seen as necessary and justified, as it was assumed that they would not necessarily limit the quality and longevity of the housing (3).

In many respects these dwellings were very successful. The housing of this time in Denmark is the largest and best equipped social housing ever built (1). But the experimental ways of building coupled with the new forms of housing and social aspirations had unpredicted results. The housing was built in a time of inexpensive non-renewable energy without concern for energy efficiency and these buildings were enormously reliant on fossil fuels. (1) When the oil crises of the 1970s hit, and energy regulations came into effect, the housing became problematic. The experiments with material and form caused urgent problems requiring renovation some within a decade of being built. The concrete needed repair, thermal bridging and comfort was a problem especially relating to balconies and windows and many housing blocks were given superficial renovations to improve the monotonous expression. (4) Additionally, for various reasons including the fact that people with options preferred single-family homes, the housing was not as popular as was expected and tended to become areas for more vulnerable segments of society such as the unemployed and new immigrants (1).

The complexity of the problems presented no easy solution and yet the housing blocks underwent expensive repair which did not provide a long term cure for the problems. In a study of renovations to Modern housing in Denmark done primarily to repair damaged concrete and improve thermal performance, it was found that the most successful renovations were the ones that did not alter the architectural intentions of the building (5). There were examples during this time of the use of external insulation which spoiled a finely detailed façade, or the painting of bright colours on a new façade superimposed on a simple Modern form. Another important finding was that the renovations generally did not result in measurable improvement to the energy efficiency (5). The research predicted that these buildings would soon need renovating all over again. This has proven true as a new wave of building renovations is being undertaken, this time focusing on social and architectural quality as well as thermal comfort, repair and energy improvement. (5) Poorly executed renovations can damage the good qualities of a building and negatively impact the architectural heritage. Koolhaas's concept of "suspending judgement" is important (6), for just because a style or form may not be appreciated instantly, does not mean it is worth destroying. There is a need to be sustainable in our architectural heritage. Therefore it is important to learn from these findings and incorporate multiple parameters in sustainable renovations of this kind.

2.0 Theory

To renovate or transform a building is often considered a sustainable strategy in itself. The relative act of being "less bad" – in not demolishing and not rebuilding - is typically



considered a lower impact approach, thereby lessening embodied energy and materials use (7). But there is no widespread agreement that “every instance of the integration of existing structures in a new building, and every qualifying extension or renovation of an existing building equals practiced sustainability.”(8)

Sustainability in architecture is often defined according to the so-called Brundtland definition, specifically with regard to meeting present needs while not compromising the ability of future generations to meet their own needs (9). Often criticized for its generality, this is a non-architecturally specific approach offering nothing specific of how sustainability looks, functions or delights. Sustainable approaches relating to building science and engineering favour technologically focused “solutions” of reducing material and energy consumption, typically relating to a predefined minimum standard. On the other hand, architectural approaches can be distinguished as striving to balance the unique concerns for a specific building, site and client. Therefore architects are uniquely placed as a profession to grasp the overall complexity inherent in sustainable transformation (10).

Sustainable renovations are often confused with energy-efficient renovations. But this distinction matters and the choice of language and priorities is key. Learning from past mistakes, future renovations must not only be “energy efficient” focusing on quantitative parameters such as energy or cost, but also “sustainable renovations” incorporating a balanced and multi-faceted building specific approach to social-architectural, environmental-energy and economic-appropriate contexts.

One such approach is that of reinterpretation (11). A reinterpretation can be defined as a renovation to a building that “augments reality”. It is a designed change to a building that “learns” from the existing building and that acknowledges, but does not faithfully preserve, its intentions. This theoretical concept can be discussed in many contemporary successful examples. In some cases this may mean reinterpreting layers of history, by removing poor quality renovations or additions that are not in keeping with the original intention.

Architects Durot, Lacaton and Vassal advocate architecturally focused parameters in sustainable renovations that they call “Plus”. Their work focuses on additive transformations, rather than demolishing, subtracting or replacing elements focusing on adding, transforming, and utilizing them (12, p29). The architects have applied this philosophy to architecturally changing and improving a series of neglected 1960s and 1970s suburban Parisian housing estates. They see potentials in architectural transformation of these buildings to achieve “generosity” and “simplicity” and they strive for a balance between social, economic and environmental concepts in their housing. When the “Plus” concept is applied to a building project, it is modified from project to project while remaining a clear strategy. For example in the transformation of the Sainte-Nazaire-Petit Maroc housing, it was part of the brief that some flats would be demolished and some newly built. The architects undertook a pre-design process of “meticulous observation”, a central part of their architectural process. Analysing what is there already culturally and environmentally and carefully formulating the design



problem to be addressed allowed them to challenge the brief. Their “Plus” proposal limited the amount of demolition through a strategy of radically reconfiguring the apartments. In their scheme, 27 flats are kept by being enlarged or improved and 18 new flats are placed on the site (12, p.195)

Reinterpretation and Plus are powerful architectural frameworks in building transformation with the potential for multi-faceted impact on a building’s sustainability. But they stand in sharp contrast to the industry standard for sustainable building transformation.

3.0 Product vs Potential

Reinterpretation and Plus advocate valuing the qualities of the existing building and responding to architectural qualities that include, for example, material, scale, form, light, thresholds, sequence of spaces and and expression. However, in contrast, the industry standards for assessing buildings with sustainable aspirations during the design stage through to operation stage are certifications schemes such as Leadership for Energy Environment and Design (LEED) (13). Due to demand, LEED have an adapted version of their rating system specifically for buildings suitable for improvement work called LEED OM+B. The scheme has quickly become very popular, with the total certified floor area assessed using LEED for Existing Buildings:Operations & Maintenance (LEED O+M) at about 3 billion square feet. This certified area has now surpassed that of LEED for new buildings. Cole terms these developments in the industry as the culture of performance assessment. (14).

LEED O+M provides a comparative, quantitative measure for a sustainable building renovation (15). Through a points based marking scheme, a numerical score and then a rating are awarded based on a renovation assessed at multiple stages. The criteria considers many aspects but weighting favours energy efficient measures. LEED O+M measures key performance areas and has minimum standards in some areas to make sure the scheme is generally balanced. The performance areas are Energy and Atmosphere (30 credits possible – 15 are for optimizing energy performance and a minimum requirement is to include 12 months of continuously measured energy use data using an onsite meter); Indoor Environmental Quality (19 credits possible, for example 2 credits can be gained for visual connection to outdoors and access to comfortable day light); Material and Resources (14 credits possible including many for user led recycling strategies); Sustainable Sites (12 credits possible, for example up to 4 possible credits for alternative commuting transportation such as working from home or multiple passengers in a private car coming to the site); Water Efficiency (10 credits possible, including 3 for efficiently watering landscaping); Innovation (6 credits possible, this is not about design innovation – for example 1 credit is gained for having a LEED accredited professional on the team and two for documenting the sustainable building cost impacts). The building’s architectural response or attitude to that context are not considered.

Globally, there is a huge opportunity for improving existing buildings and if architects do not insist on architectural criteria then these will not be considered. The profession is at risk of

losing connection and influence over key aspects of architectural design – attitude to site, environment, scale, material and form. In late 2014 UK based rating system BREEAM (16) and German scheme DGNB (17) will release updated and greatly expanded versions of their certification schemes for existing buildings. It is projected that there will be a huge increase in clients and design teams registering for green building certification schemes and renovating existing buildings.



Gyldenrisparken Housing in Copenhagen was comprehensively renovated in 2010 and incorporates architectural, social and environmental criteria in its reinterpretation of the 1960s buildings. Image: Witraz Architects

An example of a renovation that makes the most of its potential is the Gyldenrisparken housing estate in Copenhagen. Renovated by Witraz and Vandkunsten in 2010, it was nominated for a renovation prize for its architectural reinterpretation of a 1960s housing estate (18). The existing buildings were run down, poorly performing and there was a poor social environment. The prize acknowledged the scheme’s introduction of a mix of uses, improvements to the performance of the building envelope and regeneration of the outdoor spaces. The clients did not seek any green assessment ranking according to one of the recognized rating systems such as LEED O+M.

4.0 Conclusions – Architectural Frameworks for Sustainable Transformation

As shown with regard to reinterpretation and Plus, an architectural renovation must take into account as guiding aspects the social and architectural contexts of both the existing and renovated buildings. Without thoughtful consideration of these aspects, there can be no “sustainable” renovation. A simple, qualitative first step could be that rating systems such as LEED begin to take into account the age of the building, the building’s particular use, the size of the building and its capacity for improvement. These four criteria are at the heart of architectural renovation and are perhaps easier to integrate into quantitative frameworks than Reinterpretation and Plus. Customizable architectural frameworks must be explored and considered, in the same way that such quantitative systems such as LEED are developed.



Current quantitative views of assessing existing buildings such as LEED set out a strong set of criteria for lowering energy use, improving efficiency and generally creating a more comfortable building. But in order to be truly sustainable, the renovation sustainability criteria must be robust and impact the environmental, social, and architectural criteria. Current systems such as LEED use criteria that neglect the social and architectural sustainability of the building, which can be considered key aspects in a renovation that make a building need renovating all over again.

New and truly sustainable renovations need to be robust from a social and architectural viewpoint and also meet tightening energy and climate goals. Through layering a customizable architectural framework such as Reinterpretation or Plus onto the typical energy-focused parameters we can improve the social- architectural sustainability of these buildings to allow them not only prolonged use but potentially improved qualities of continued life.

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Eco-responsible plan and design. Processes, strategies and tools towards environmental assessment in Architecture

Abstract: *How the building sector can actively contribute to reach the european purpose of energy efficiency in an eco-responsible way on a local scale?*

This research analyses instruments, indicators and procedures for the environmental sustainability evaluation available in literature; according to Agenda 21's local goals in terms of sustainability and recovery of the existing heritage, identifies the implementing subjects and the operating instruments to promote ecoresponsible actions of intervention on building heritage there where there is still no local legislation to which to make reference, like in Sardinia (Italy); tests and verifies environmental sustainability evaluation systems at urban and building scale by applying specific rating systems and procedures based on the Life Cycle Assessment approach using real case-studies.

In light of the topical issues discussed, the research's solutions intend to propose an hypothetical path towards the environmental assessment in architecture that could grow from a local to a wider scale.

Sustainability, recovery, rating systems, Life Cycle Assessment approach

Introduction

Three big sectors, transportation, buildings and industry, are the main culprits of environmental damaging impacts by consuming more resources and by generating more emissions than all the other human activities put together. Data about building impacts on environment are even more alarming. From now onwards it needs to take more responsible measures towards Environment in order to give the natural heritage back to future generations.

The unscrupulous exploitation of natural resources derives from the anthropocentric concept that considers Nature as a human means and as a plentiful resource able to regenerate indefinitely. With the industrial Revolution, problems connected to resource exploitation and pollution increased: therefore, ecologist cultural trends started to spread, influenced by the environmental issues, the uncertainty of Nature's infinitude and of healthy effects of technology. In the building sector this led to the birth of the latest specialized branches of knowledge called 'ecourbanism', 'ecodesign' and 'bioarchitecture'.

All literary production about environmental issues, by Daly, Prigogine, Capra, Odum, and about the interaction between environmental, productive and economical systems and their crisis, by Commoner, Boulding, Georgescu-Roegen, constitutes the beginning of the literary and scientific path that has lastly lead to some normative actions.

The first implementation document was published in 1997. It was the Kyoto Protocol that intends to promote control measures of environmental pollution and to incentivise measures in the usage of renewable energy sources.

In the energy field, Europe issued some important directives implemented by national decrees of Countries members. Italy acknowledged only the first directives. Nowadays in Italy there are just a few obligatory measures in regard to environment. Only a few regions have a protocol or have simple measures in support of their policies for the environmental assessment of buildings.



In Sardinia, region in Italy, there is still no local legislation to which to make reference. To evaluate buildings' sustainability it needs to revert to a national protocol, but it is not obligatory.

This research intends to create a local protocol to assess buildings interventions from the environmental point of view.

It proposes a bottom-up approach that, starting from considerations based on local case studies of settlement and building procedures, may lead to guidelines in favour of environmental sustainability able to integrate the technical standards of implementation of local restoration plans.

The first step of the research has been to define the meaning of environmental sustainability at urban and building scales by analysing processes, strategies, instruments and case-studies realised world- and nationwide.

Processes, strategies and instruments towards building environmental assessment: from general observations to local experimentations

The environmental issues and the purposes suggested by this research become part of the international and national debate that finds the only solution in the culture of sustainability. In the last fifteen years, the discussion about environmental issues has lead at convergence of culture of sustainability to culture of recovery and of reduction of resources consumption. That means, in the building sector, to retrofit existing buildings, to use ecological materials and constructive solutions and to recycle building elements.

After the definition of the reference framework about environmental sustainability in the building sector at the international and national scale, the research supposes eco-responsible modus operandi by subjects who want to act in an environmentally friendly way. This part of the research starts from a professional experience of urban planning that I lead with a team of engineers and architects in a small village of Sardinia, Sedilo. That experience has turned out to be the right occasion to suppose eco-responsible actions of investment on existing architectural heritage in a project aimed at the preservation and exploitation of existing historical and cultural aspects. The main purpose is to transfer these actions to a bigger scale following a bottom-up approach that, starting from the example of local policies of eco-responsible government of territory, could suggest the guidelines for a regional protocol of building environmental assessment.

A case-study at urban scale: materials, methods and results

The research analyses a local historical context set in the Sardinian island that contains certain representative aspects of this region about housing density, services, culture, constructive characteristics and typologies.

The research studies pre-modern and modern architecture's characteristics of Sedilo. In particular, we have focused the attention on aspects related to the constructive characteristics and typologies of buildings, the site morphology, the constructive technologies and techniques commonly used, materials and their processes of extraction and manufacturing, heating, cooling and ventilation systems and the water use.



This analysis has led to the definition of a cognitive framework composed of formal aspects and common local procedures of buildings, concerning extraction, transportation and manufacturing of constructive elements, and the realization, management, maintenance and buildings' end use.

The first reflection that arises from this study is the gradual extinction of material and immaterial characteristics of the analysed building heritage: such as the manufacture of materials and energy used to build and to preserve this heritage, the traditional knowledge, the practices and the social aspects of that context.

A second reflection is the growing soil consumption in an area characterized by its gradual depopulation, as it happens in lots of sardinian and italian urban.

These qualitative reflections highlight the need to quantify the un-sustainability of human habits and actions, in particular, concerning building and architectural choices and to define new rules related to the restoration of the ancient relationship site-building and the use of local resources. The analysis of existing buildings in Sedilo shows that traditional buildings are reputedly more befittingly than modern buildings (after 1970) especially if we consider environmental and energy criteria of building retrofit.

The process of synthesis of the analysis of existing building heritage of Sedilo allowed the definition of the sustainable aspects of the traditional architecture.

These aspects have been synthesized in 14 criteria-form that represent the main principles of urban and building sustainability found in Sedilo. They are:

- Relationship between building and its pertinence area (“corte”);
- Building orientation;
- Relationship Area/Volume;
- Relationship building-site morphology;
- Relationship Building-Services;
- Distance from pollution sources;
- Building matt shell;
- Natural lighting and screening systems;
- Natural ventilation;
- Reduction of energy consumption;
- Recovery and reuse of materials;
- Use of ecological materials compatible with traditional materials;
- Maintenance of water structure of territory and the reuse of meteoric water;
- Use of vegetation as natural bioclimatic regulator.

Every criteria-form includes the aspects of sustainability and of un-sustainability and the guidelines of environmental and energy building retrofit of existing building heritage.

Guidelines are represented in three different forms according to the regulator instrument supposed and adopted:

- simple considerations followed for the definition of the intervention in Urban planning experience of the historical centre;
- eco-responsible rules for building to complete the technical standards of implementation of local restoration plans;



- evaluation forms for a local protocol of energy and environmental assessment of interventions on existing building heritage.

It's difficult to introduce environmental and energy measures of building retrofit into historical contexts because these measures must be careful and must depend first of all on the preservation of existing architectural and historical heritage. At the same time, these rules are felt by inhabitants of historical centres as further bonds on their own properties.

Moreover, technicians are called to draw up new papers about their building choices.

They may seem as impediments to urban sustainable development. But, in reality, the rating systems processed are easy instruments for eco-responsible projects and buildings and their current use may address a real sustainable development based on the correct exploitation of local material and immaterial resources.

The aspects of sustainability and unsustainability studied during the analysis of the existing built heritage of Sedilo are translated in simple rules of eco-responsible building that exploit the natural interaction between the building and the site where it was built and that are included among the technical standards of implementation of the local restoration plan. Then they are simply synthesized in evaluation forms that contain technical requirements of energy and environmental sustainability.

These evaluation forms are studied on existing international and national protocols based on multicriteria analysis (such as nationwide ITACA Protocols of Puglia, Tuscany, Umbria and Basilicata, and worldwide the LEED , BREEAM, HQE, CASBEE environmental assessment methods).

Their synthesis and adaptation to the studied context lead to the individuation of appropriate indicators of the environmental sustainability that, once converted into planning suggestions, will complete technical standards of implementation of local restoration plans and that, if supported by regional and local financings, may promote local policies of sustainable development of the territory at economic, social and environmental scale.

Multicriteria evaluation systems are flexible instruments that can be easily adopted to a large urban scale of reference, by changing local environmental indicators and by adding new technical requirements according to the new context analysed.

A case-study at building products scale: materials, methods and results

Construction is not an environmentally friendly process by nature. The cumulative environmental impacts of building processes have been increasing in the world due to a large number of ongoing construction projects. Most of these impacts are related to the use and maintenance phases of a building. At the environmental level, the building sector is directly and indirectly linked to the consumption of a great amount of natural resources and to the production of a relevant quantity of residues. The use of improved materials and building technologies can contribute considerably to better environmental life cycle and then to the sustainability of buildings.

Life Cycle Assessment (LCA) is a systematic approach to evaluate the environmental impacts of products or processes during their whole life-cycle. It is basically quantitative, and it considers the material and energy flows. The methodology is born in the industrial sector and



has been developed and used for long time, but it was only standardized in 1996, by the International Organization for Standardization (ISO14040-42). The LCA fits perfectly with the level of single product or material, but it is generally accepted to be applied for building products and whole building, too. Environmental performance is generally measured in terms of a wide range of potential effects, such as global warming potential, stratospheric ozone depletion, formation of ground level ozone, acidification of land and water resources, eutrophication of water bodies, fossil fuel depletion, water use, toxic releases to air, water and land. LCA is very important to compare several possible alternative solutions, which can bring about the same required performance but which differ in terms of environmental consequences. With the development of energy-efficient buildings and the use of less-polluting energy sources, the contribution of the material production and end-of-life phases is expected to increase in the future. The aim of the list of the impact categories is to represent a quantified image of the environmental impacts and aspects caused by the object of assessment during its whole life cycle.

It is widely recognised in the field of Building Sustainability Assessment that LCA is the best method for evaluating the environmental pressure caused by materials, building assemblies and the whole life-cycle of a building. Although there are several recognized LCA tools, these tools are not extensively used in building design and most of building sustainability assessment and rating systems are not comprehensive or consistently LCA-based. Reasons for this failure are above all related to the complexity of the stages of a LCA. Besides being complex, this approach is very time consuming and therefore normally used by experts at academic level. For these reasons most of the building sustainability assessment methods have relied on singular material properties or attributes, such as recycled content, recycling potential or distances travelled after the point of manufacture.

The two most important barriers to the quantification of the environmental indicators and therefore to the incorporation of LCA in rating systems are: a lack of LCI data for all building products and the inherent subjectivity of LCA. Environmental Product Declarations (EPD) are a good source of quantified information of LCI environmental impact data. In order to potentiate their use, rating systems should be based in the same LCA categories. Nevertheless, at the moment, there are important limitations on this approach, since there is only a small number of companies either having or making publicly the EPD of their products.

This research presents some solutions to overcome the difficulties in using an LCA-based approach to support decision-making which aims at promoting lower environmental building design since the earlier design phases. The development of evaluation methods based on the most common sustainable indicators actually used and present in scientific literature, as the embodied energy of the most used building technologies and materials, is a good solution to overcome some of the presented barriers that are hindering the widespread use of the LCA-based approaches by the design teams.

The third part of the research, starting from the scientific description of LCA procedure, presents a simpler procedure of sustainability evaluation, according to an LCA-based approach, to support the design phase of a retrofit intervention of a traditional existing



building. The procedure proposed analyses different retrofit solutions of a traditional matt shell in basalt in terms of embodied energy. Data about the embodied energy of the technical solutions selected derive from scientific literature and consider only the non renewable embodied energy calculated in MJ equivalents. Using these simple data, designers are able to take with more awareness the earlier decisions about materials choice.

The research compares six different retrofit solutions of an external wall in basalt:

- internal insulation board in EPS or in cork material;
- external insulation board in EPS or in cork material;
- double insulation boards in EPS or in cork material;

All the different solutions present similar thermal performance:

- a steady state thermal transmittance below $0,40 \text{ W/m}^2\text{K}$;
- a dynamic thermal transmittance below $0,12 \text{ W/m}^2\text{K}$;
- the absence of internal condensation phenomena.

Which solution was calculated in terms of total embodied energy of the whole shell's section.

Firstly, quantitative results highlight that natural insulation boards, like cork boards, are more ecological in terms of embodied energy than EPS ones. Secondly, they underline the importance, in a comparing process, of correctly defining the functional unit, which is the quantity of material able to ensure best performance.

More generally, from the qualitative point of view, the first result emerging is the actual sustainability of the retrofit of an existing building component, such as a traditional wall in basalt, instead of the realization of a new one in terms of resources consumption and manufacturing residues.

Factors that increase the ecological footprint of a new building based on a common local constructive process are:

- the predominance of wet working procedures and the manufacturing waste resulting;
- a high number of working phases;
- use of inferior materials, usually slow performing and provided with huge environmental burden (due to extraction, transportation, use of toxic substances, short-life related to incompatibility with other materials);
- a greater energy consumption for the building management, due to heat loss through thermal bridges, the slow exploitation of solar gain and passive air-conditioning systems, the unsuitable thermal mass and building envelope energy efficiency, the over engineering of cooling and heating systems;
- lack of attention at the decision-making level to the maintenance phase and its importance in terms of environmental and energy burden.

This may seem to be an extremely critical point of view about local building processes, but the truth is that most local building workers follow these procedures, and it happens for these reasons: an insufficient attention to existing building potentiality and a slow cognizance of its "energy memory"; indifference to environmental issue; lack of awareness of importance of our choices; use of proved building materials and constructive techniques and reluctance to experiment innovative solutions and new materials; a local market blind to environmental



issues and to ecological materials; the absence of a strong regional and local policy that promotes eco-responsible actions.

Another result of this work is the certification, thanks to LCA-based approaches, that lots of materials were commonly marketed as “ecological”, when in fact they were not. The target of “ecological” must be defined in terms of CO₂ emissions, energy consumption, water and raw materials use, eutrophication, soil acidification, toxicity, depletion of the ozone layer, photosmog formation and residues’ production.

We know that embodied energy is not sufficient to assess the whole life-cycle of a product, but it allows to develop simple evaluations about environmental sustainability in the early design phases. And it is a first step towards a more complete procedure of environmental assessment in building sector where the only requirements considered are technical-type.

Conclusions

In light of early assumptions and results obtained, this research demonstrates how, in a bottom-up approach, we could use multicriteria evaluation systems and LCAs analysis to support a more ecologically sustainable policy. The use of these procedures allows to make eco-responsible choices and to build with due respect to environment.

By combining considerations arising from LCA studies and from green building common procedures, we can define a protocol composed of guidelines for environmentally sustainable planning. The application of these methodologies to a real context allows us to find technical standards able to interpret and to reevaluate local characteristics.

In view of the huge italian historical building heritage and agreed assertion that restoring an existing building is more ecologically sustainable than new building, we can use these instruments by defining technical standards of environmentally sustainable implementation in local restoration plans.

The analysis of local context must be not only about historical building, but also about the following characteristics:

- natural and climatic environmental factors (such as data about umidity, rainfall and sunlight);
- environmental, water and energy resources and, in particular, renewable sources already existing or persuable;
- anthropogenic environmental risk factors;
- local resources and products.

These factors would allow us to pursue the following goals:

- in the absence of regional legislation, to develop local urban plans based on environmental sustainability from city plans of implementation to building design, taking care to ensure water and energy saving, soil permeability, use of reusable, local and healthy building materials;
- to place actual national legislation about environmentally sustainable building in local context, in order to characterize the effective and efficient players of local sustainable development;



- to suggest to technicians eco-responsible actions in the building materials and techniques choice process;

- to promote building restoration to rivitalise thinly populated or unpopulated areas as our historic town centres are.

The research does not intend to obstruct the use of certain materials by promoting other ones, or to discredit local building processes.

Its main purpose is to pursue a capillary action of communication and awareness towards local authorities, technicians, economic operators, citizens, so as all parties could be aware of social benefits of sustainable housing and could become protagonists of change.

This is the path indicated by this research in order to contribute to sustainable development at the local level in the building field.

It is an “environmental” development that intends to value local natural capital in order to improve environmental, architectural quality and the urban settlements’ healthiness.

It is an “economic” development by promoting the harmonious development of that area and its productive activities.

It is a “social” development because it needs synergies and participating stakeholders, that represent at the same time the protagonists and the acquirers of change. This work represents the starting point for larger research that needs to be continuously kept up-to-date. It is desirable to extend the study to a larger scale in order to promote the sharing of local natural, productive and social resources.

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Session 105:

Up to what degree are eco-efficiency management tools developed?

Chairperson:

Sauer, Bruno

Director Técnico GBCe, socio Bipolaire Arquitectos. Profesor Universidad Europea de Valencia



Development of the rating system for environmental performance of city block (CASBEEUD) and Case studies

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Abstract: *CASBEE-UD can be used to evaluate the environmental performance of urban development projects in the district where there are several architectural constructions, roads, public squares, green spaces etc. The first version of CASBEE-UD was released in 2006, and the following year, the current version of CASBEE-UD, which can be used more widely and easily than the first version, was made available to the public. CASBEE-UD has thus served as a useful tool to developers and city/district planners. Later, in 2011, the Great East Japan Earthquake struck our nation and since then the necessity for more advanced local safety performance and improved stability in the energy-related environment has been recognized highly. " Low Carbon City Promotion Act " was enacted in 2012. Demand of assessment tools can be evaluated has been increased in accordance with the framework of the law. In response to this trend, CASBEE-UD tool be in the process of major revision.*

Keywords: *CASBEE, Low-Carbonization of cities, Urban development*

1. Introduction

CASBEE-UD can be used to evaluate urban development projects on the ground where there are several architectural constructions and other areas for various purposes such as roads, public squares and green spaces. The first version of CASBEE-UD was released in 2006, and the following year, the current version of CASBEE-UD, which can be used more widely and easily than the first version, was made available to the public. CASBEE-UD has thus served as a useful tool to developers and city/district planners.

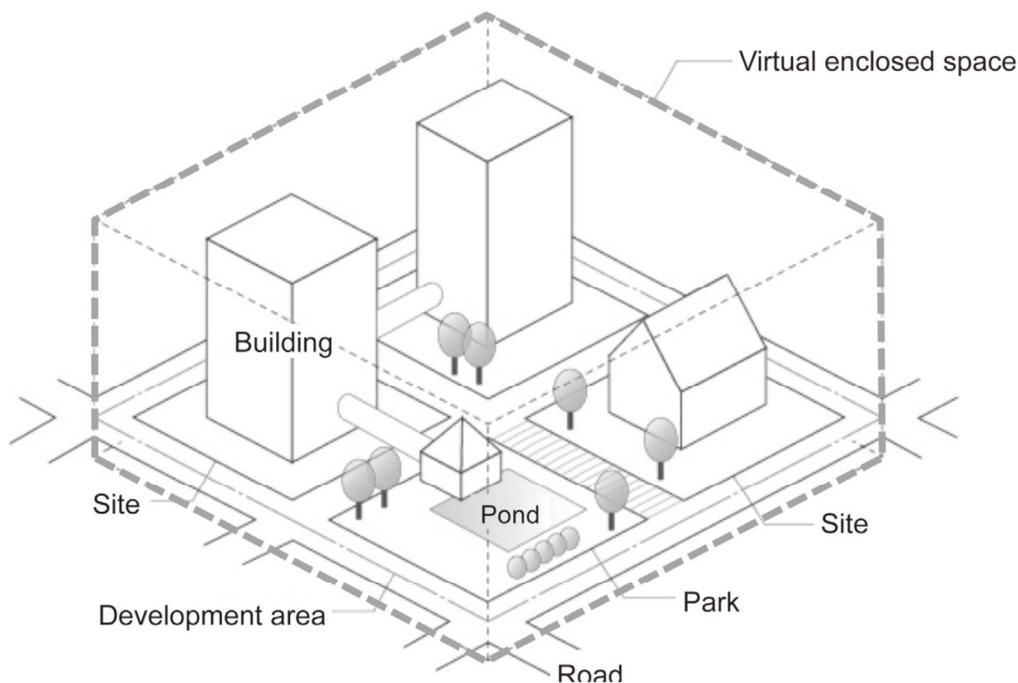


Figure 1. Assessment subjects for CASBEE for Urban Development

Later, in 2011, the Great East Japan Earthquake struck our nation and since then the necessity for more advanced local safety performance and improved stability in the energy-related environment has been higher than ever. In 2012, the “Low Carbon City Promotion Act (Eco-City Act)” was established, resulting in an increased demand for assessment tools that can organically fit and work together with the Act. In response to such a trend, drastic revision of the CASBEE-UD tool is currently underway in cooperation with the Housing and City Bureaus of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). The outline of the drastic revision plan is given below.

2. Assessment method

As in the case of many other CASBEE family tools, the assessment of CASBEE-UD is conducted from two perspectives: Q_{UD} (environmental quality inside the virtual enclosed space boundary) and L_{UD} (environmental load on the outside of the boundary). The comprehensive assessment result is expressed as the built environment efficiency of an urban area of interest (BEE_{UD}), which is obtained by Q_{UD}/L_{UD} . The subscript UD of Q_{UD} , L_{UD} and BEE_{UD} indicates that these are the results of CASBEE-UD assessment. What to assess is described in detail in the later sections, and the key concept here is that the assessment of Q_{UD} is based on the triple-bottom-line approach and L_{UD} is evaluated according to how effectively low-carbon initiatives are carried out. The scoring criteria have been established in such a way that better results are assigned to the projects planned in accordance with the compact design of an urban structure, because it will be increasingly important to efficiently utilize the land and social capital in our country, which is now facing the situation of fewer children, an aging society and depopulation.

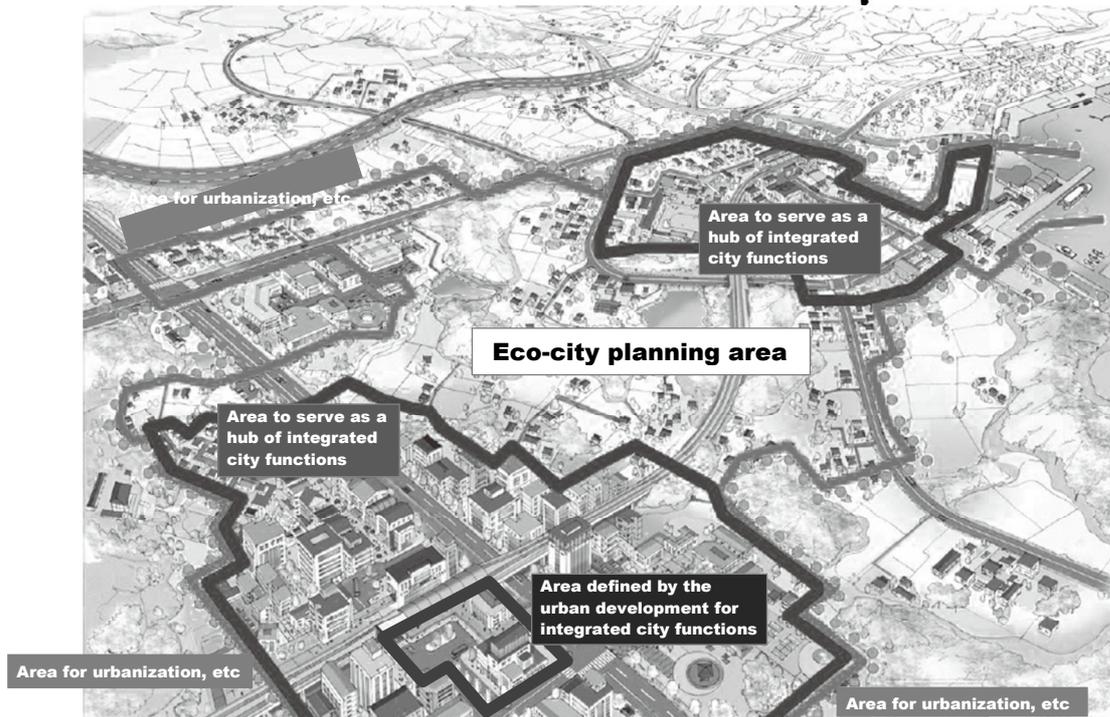


Figure 2. Illustration of the concept of areas defined by the Eco-City Act (Source: “Example of areas defined by the urban development project for integrated city functions,” available on the website of the Ministry of Land, Infrastructure, Transport and Tourism-modified by the author)

In the assessment, the boundary of an area concerned, which functions as the virtual enclosed space boundary, is determined based on the regulations and systems of relevant laws on construction and urban development (for example, regarding urban redevelopment projects, specific blocks and district planning) to which a project of interest is subject. As a natural consequence, any project for assessment is assumed to be executed under a certain defined policy for development. One or more districts can be addressed by the project. The scale of areas to be assessed conforms to that of the “urban development project for integrated city functions” provided in the Eco-City Act (Figure 2).

3. Assessment of Q_{UD} (Environmental Quality of an urban area of interest)

The environment, society and the economy, all of which are together defined as the triple bottom line, are designated as three Major Items in the assessment of Q_{UD} and each assessment item is assigned to one of these three groups. Each “Major Item” consists of several Middle Items, each of which consists of Minor Items. Table 1 gives the details of the assessment items. Regarding scoring, in accordance with the common method among the CASBEE family tools, each Minor Item is marked in a range of five levels and their scores are added up to calculate the total assessment results of Middle Items, Major Items, and Q_{UD} , respectively. Because the triple-bottom-line approach has become a norm when sustainability is discussed, it is used as the base for the Q_{UD} assessment. However, it should be remembered that “realization of a lower carbon footprint,” which is a crucial issue in the field of the global environment, is addressed in the assessment of L_{UD} . Below is the supplementary explanation



of the three Major Items, whereby the perspective and principles of the evaluation of assessment items are given.

1) Environment: The three Middle Items (i.e., Resources, Nature, and Man-made Objects) form the base of the assessment of the environmental quality entailed by an urban development project. In the first item, “Resources,” the key points for assessment may be considered to be associated with the measures for reduction of environmental load (L) rather than the quality of environment (Q), despite which these are included in the assessment of Q. This is because the emphasis is placed on an aspect of the “improvement of environmental quality” such as conservation of water resources and creation of a society opting for recycling, which can be achieved by each measure. In the second item, “Nature,” the substantiality of natural environment/space in an urban area of interest is evaluated in terms of greenery and biodiversity. Lastly, with regard to “Man-made Objects,” the environmental performance of architectural constructions in an urban area of interest is used as a representative indicator. Specifically, the assessment is based on the frequency of use of CASBEE tools for architectural/real estate market purposes and the results of such CASBEE assessments.

2) Society: The assessment is conducted in terms of social performance that can be achieved through a project of interest in itself as well as how much the project or its execution can contribute to better social quality in the neighborhood of a local area designated by the project. The base of the assessment is also formed by three Middle Items. In the first item, “Fairness and Legality,” the appropriateness according to the relevant laws on urban development and the practicality of management systems (especially, to be in harmony with the local community) are evaluated. The next item, “Safety and Security,” addresses the anti-disaster or anti-crime performance of an urban area concerned, which has a direct connection with the sense of security of residents and visitors, and the strength or robustness that supports the sustainability of local communities. The last item, “Amenities,” is assessed not only from the viewpoint of accessibility to various service facilities for convenience of everyday life, but also from the viewpoint of improvement of local value such as utilization or creation of historical/cultural assets and contribution toward a better townscape.

3) Economy: The assessment is conducted in terms of economic potential which a project of interest has in itself as well as the possible economic contribution of the project towards the value and functionality of a local area designated by the project and the whole city in which the area is located. As in the case of the previous Major Items of “Environment” and “Society,” three Middle Items are used for assessment of “Economy.” In the first item, “Transportation and Urban Structure,” the effectiveness of transporting systems that underlie economic activities and the utilization of location/site potential from the perspective of urban development are evaluated. Regarding the next item, “Potential for Growth,” the key points to be assessed include the population (living population and visiting population including employees) as a fundamental indicator of economic potential of the project and the practicality of schemes to activate economic activities. Lastly, “Efficiency and Rationality” deals with information and energy systems in terms of effective management and services for users in an urban area of interest.



Table 1. Assessment items included in “QUD: Environmental quality and performance in urban development”

Major Item	Middle Item	Minor Item	Key assessment points, assessment method, etc.
Q _{UD} 1. Environmental	1.1 Resources	1.1.1 Water resources	Use of rain water, introduced level for a gray water system, sewage treatment level, permeation of rain water through the ground, etc.
		1.1.2 Resource circulation	Initiatives for re-use/utilization of waste, and use of locally-produced materials or recycling products
	1.2 Nature (greenery/biodiversity)	1.2.1 Greenery	Greenery on the ground, rooftop and wall surfaces
		1.2.2 Biodiversity	Initiatives for creation of patches and corridors, etc., and conservation of natural resources, consideration of geographical characteristics
1.3 Man-made objects (constructions, etc.)	1.3.1 Buildings designed for environment	Frequency of conduct of CASBEE assessment on building	
Q _{UD} 2. Society	2.1 Fairness and legality	2.1.1 Legal obligations (compliance)	Compliance of the relevant laws on development, and the level of initiatives taken for voluntary conduct of prediction and monitoring
		2.1.2 Area management	Establishment of a management group by parties involved, and the validity of foundation for its sustainable operation such as finance
	2.2 Safety and security	2.2.1 Disaster prevention	Understanding of disaster hazard maps and precautions against them, and establishment of BCP or LCP on the area
		2.2.2 Traffic safety	Measures taken for road safety such as secured sidewalks
		2.2.3 Security	Measure taken for security of the area
	2.3 Amenities	2.3.1 Convenience/ Welfare	Distance from retailers, medical facilities, etc.
2.3.2 Culture		Initiatives for creation of new cultural movement and preservation of historical/ cultural heritage, creation of townscape or view, and harmony with the surrounding views	
Q _{UD} 3. Economy	3.1 Transportation and urban structure	3.1.1 Transportation (flow of people and goods/products)	Maintenance condition of transportation facilities, rationalization of physical distribution logistics, joint deliveries, etc.
		3.1.2 Urban structure	Consistency with schemes such as master plans for urban development, handling of brownfield sites, etc.
	3.2 Potential for growth	3.2.1 Population	Estimated increase/decrease in population compared with the previous level
		3.2.2 Economic growth	Level of initiatives taken for creating an active local economy
	3.3 Efficiency and rationality	3.3.1 Information system	Flexibility of district information environment, usability, etc.
		3.3.2 Energy system	System of energy supply and demand, scalability, renewability

4. Assessment of L_{UD} (Environmental Load of an urban area of interest)

In CASBEE-UD, CO₂ emissions induced by a project of interest (on a scale of a district or local area) are calculated and converted into an L_{UD} score through a series of procedures to obtain a standardized indicator. The outline of the procedures is given below.

i) Calculate the annual CO₂ emissions induced by the execution/operation of a project of interest based on two scenarios: the case of business as usual (BAU) with no low-carbon initiatives being taken and the non-BAU case in which the initiatives are in effect.

ii) Estimate the population after the project comes into effect, using the common equation that has been defined in advance. Divide either of the above-obtained results by the estimated population to calculate annual CO₂ emissions per person (i.e., L_{BAU} and L_{non-BAU}). →The difference between these two (LR = L_{non-BAU} - L_{BAU}) is considered as the CO₂ reduction attempted by the project.

iii) Express the obtained L_{non-BAU} as a score ranging from 0 to 100 points. The L_{non-BAU} score should be determined according to the position of L_{non-BAU} falling on a logistic curve that is drawn on the assumption that 75 points in the score correspond with the obtained L_{BAU} and 25 correspond with about 20% reduced value of the obtained L_{BAU} (i.e., 0.8 x L_{BAU}). In the assessment of L_{non-BAU}, the “Manual on Low-Carbon District Planning,” which was released in accordance with the enforcement of the Eco-City Act, is used as a reference to consider

effective low-carbon initiatives. That is, of the initiative examples provided in the manual (Table 2), those regarded as being especially effective in a project of interest are selected for calculation. In CASBEE-UD, by dividing (buildings, transportation, green) in three of these items, and calculates the reduction of CO₂ emissions each respectively.

Table 2. Assessment items included in “L_{UD}: CO₂ emissions as a environmental load”

Main Items	CO ₂ emission reduction measures of interest	
L _{UD1} Transportation	[1]	Improvement of an area to serve as a hub of integrated urban functions and appropriate locations of other urban functions
	[2]	Encouragement of use of public transportation systems
	[3]	Rationalization of freight transportation
	[4]	Facilitation of reduced CO ₂ levels emitted through use of cars
L _{UD2} Buildings/ Homes	[5]	Utilization of public facilities to install systems for the effective use of fossil fuels and the adoption of non-fossil energy use
	[6]	Promotion of lower-carbon buildings
L _{UD3} Greenery	[7]	Preservation of green spaces and promotion of greenery

5. Case Study of the assessment trials

The framework of the tool is being polished up while it has been used on trial for several projects. The example given below is a trial case regarding the assessment of an area designated for a public welfare facility at the East-Exit North District of Tamachi Station in Minato Ward, Tokyo (hereafter referred to as the “T Project”). The T Project can be summarized as the designated area of 4.6 ha (of which 1.2 ha is the green space), an aggregate of four buildings containing the cultural hall/theater, sports center, medical clinics, nursery school, etc., and the total floor space of approximately 57,000 m². With regard to the Q_{UD} assessment, the score attained in “Environment” was 3.4 because of reasons such as appropriate consideration for biodiversity and a high greenery ratio achieved by securing a large green space in spite of the facility being located downtown. In “Society,” the facility itself serves as the disaster prevention base equipped with various service functions, which was highly rated in terms of safety/security and amenities to produce a score of 3.8. When it came to “Economy,” potential for growth remained average despite the effect of the introduced district heating/cooling system, resulting in a score of 3.5. Thus, the obtained final score of Q_{UD} was 3.5.

Figure 3 shows the whole process of calculation in the assessment of L_{UD}. Regarding all the buildings designed by the project, CO₂ emissions in the case of BAU were estimated based on factors such as the floor area by building type and carbon intensity, to produce the results of 5,084 t-CO₂/year in the transportation sector and 6,604 t-CO₂/year in the household sector. On the other hand, the downward arrows in the figure represent the reduced amounts of CO₂. Therefore, the annual CO₂ emissions in A are 11,688 (t-CO₂/year) as BAU; the total reduced amounts are 2,292 (t-CO₂/year); and the total CO₂ emissions when the initiatives are in effect are 9,393 (t-CO₂/year) as non-BAU. Either value of BAU and non-BAU is divided by the estimated population of 2,726, thus reduction rate of CO₂ emissions between BAU and non-BAU is 19.6%, Score of LR is equal to 4.11 (1 < SLR < 5).

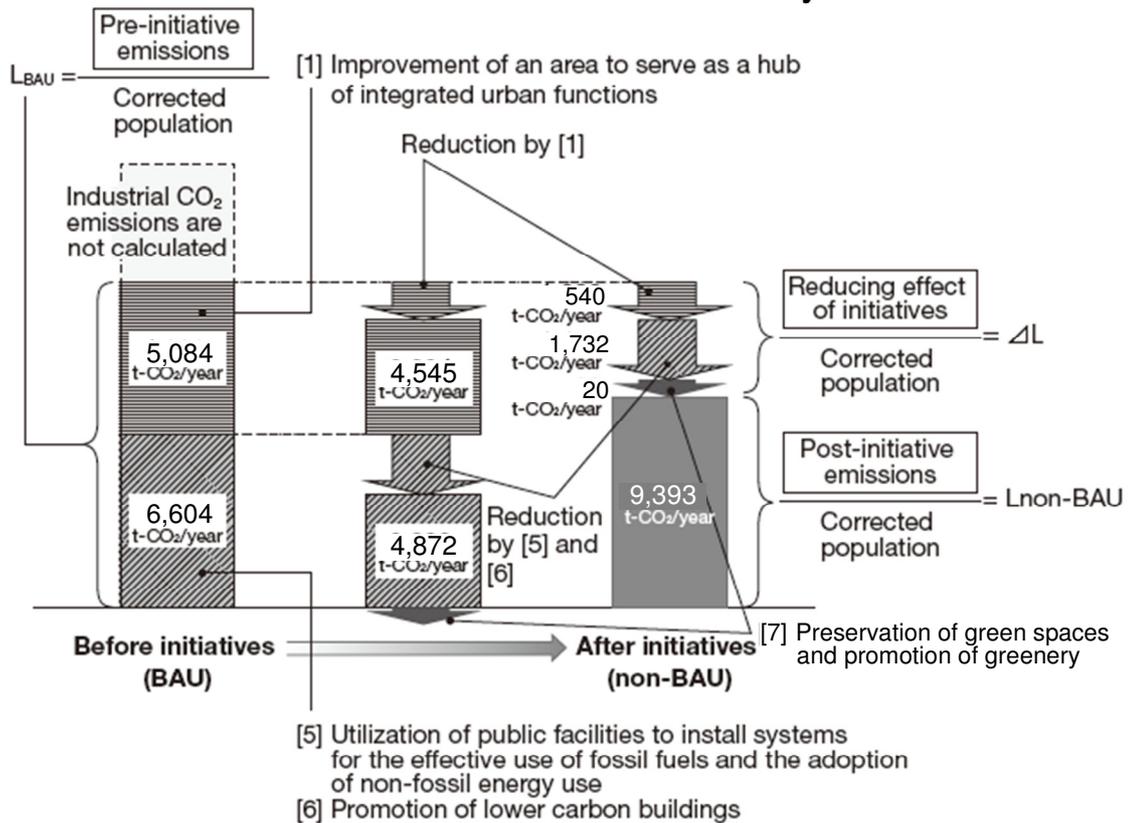


Figure 3. Example of calculation process for the estimation of L_{UD} -reducing effect of initiatives

Although the accurate estimation obtained through drawing a logistic curve is in progress, the L_{UD} score in this case is expected to be around 20. Therefore, dividing the Q_{UD} score by the L_{UD} score (i.e., $[25 \times (3.5 - 1)]/20$), the built environment efficiency of the urban area designated by the project (i.e., the BEE_{UD} score) will be 3.0, which is a value estimated with use of some provisional conditions.

Conclusions

In response to the social situation of the Great East Japan Earthquake, such as the revision of the laws of Japan, CASBEE-UD is advancing a large revision. For Q items in CASBEE-UD new, by incorporating the concept of triple bottom-line environment, society, the economy, the object of evaluation is the CO₂ emissions of the target city block for L items. Revised version of CASBEE-UD has been released in July 2014.

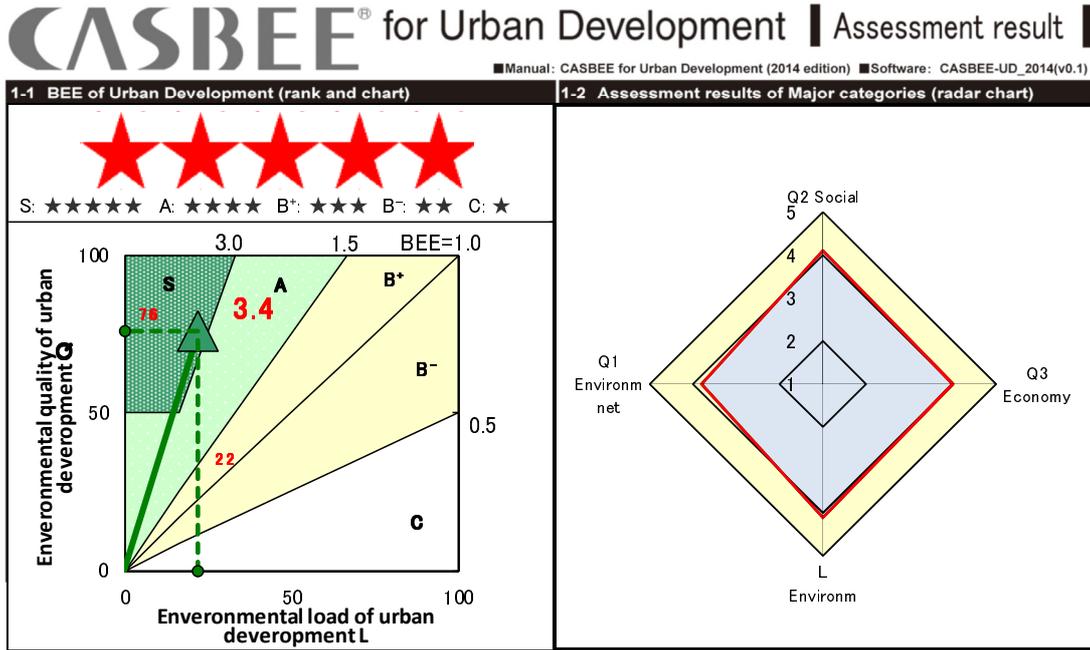


Figure 4. An example of CASBEE-UD evaluation (image)

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EcoBalance model for assessing eco-efficiency of urban development

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***Abstract:** Sustainability of urban development can be assessed on different levels: neighborhoods, municipalities, regions etc. The EcoBalance model was developed in the early 1990s to assess sustainability of urban development and it has been applied in numerous cases at various planning levels in Finland: detailed plans, local master plans and regional plans. Assessment covers all structures: buildings and infrastructure, and transportation caused by inhabitants and work places of the area. The EcoBalance model estimates the total consumption of energy and other natural resources, the production of greenhouse gas and other emissions and the costs caused directly and indirectly by urban form on a life cycle basis. The results of the case studies provide information about the ecological impacts of various solutions in urban development. According to the research results urban planning solutions and decisions have large-scale significance for sustainable development of the built environment.*

Sustainability assessment, eco-efficiency, EcoBalance model, urban development, urban planning, impact assessment

Introduction

An ecologically sustainable area can be described as an area which requires the supply of as little energy and raw materials as possible (especially non-renewable materials), and which produces the minimum of harmful emission and wastes from all building and operating processes on a life cycle basis. A sustainable area should also offer people a good living environment and be economically affordable [1]. In order to evaluate the ecological sustainability of urban development it is necessary to develop appropriate assessment methods. Methods for sustainability assessment are described, for example, in COST Action C8 “Best Practice in Sustainable Urban Infrastructure” [2], in SB10 Helsinki Conference proceedings [3], in SB11 World Sustainable Building Conference Proceedings [4], in BSA 2012 Conference Proceedings [5] and SB13 conference series [6].

The main goal of the research referred in this paper is to present a general view of impacts of urban planning choices on ecological sustainability of urban form. The research is based on case studies during 1992 – 2011, developing and applying the EcoBalance model for assessing impacts of urban form on a life cycle basis at various planning levels: residential area (detailed plans), municipality (master plans) and regional (regional plans) levels [7-19]. Results of the case studies show how ecologically sustainable various areas are, which impacts appear from area to area and from one urban form level to another, the essential

choices of urban planning and transportation, and how to act to promote ecological sustainability in urban development.

The EcoBalance model

The EcoBalance model estimates the total consumption of energy and other natural resources, the production of emissions and wastes and the costs caused directly and indirectly by urban structures and transportation on a life cycle basis, e.g. [20-25]. (Figure 1)

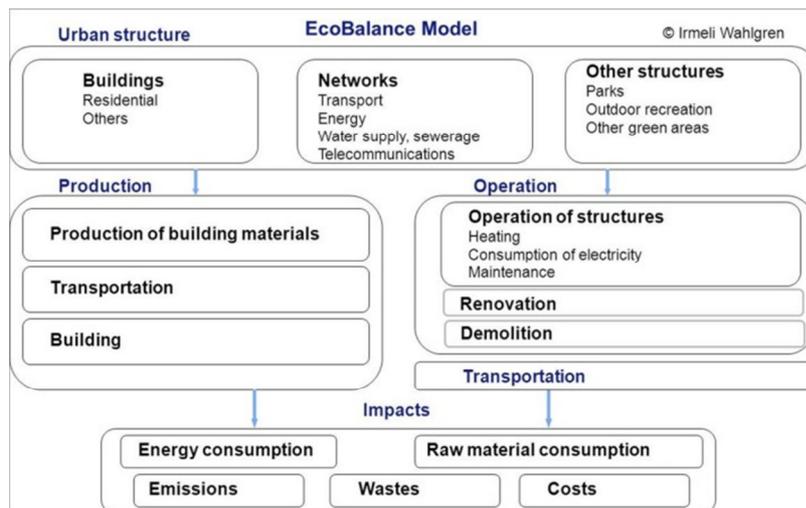


Figure 1. Structure of the EcoBalance model, e.g. [21-25].

The EcoBalance model is divided into three sub-models: production, operation and transportation models. The ecological balance sheet has the following dimensions: consumption of energy (primary energy), consumption of natural resources (building materials, fuels, water), emissions, wastes and costs. All impacts are measured with their natural dimensions (tons, kWh, m³, euros).

The EcoBalance model includes all urban structures: buildings, technical infrastructure and green areas. The model covers the whole life cycle of urban structures, starting from the production of building materials and fuels and continuing through maintenance and the use of the structures, as well as transportation in the urban structure, and finally to the demolition of the structures. The input for the model is the volume information about the structures of the area and transportation. The details of the information depend on the planning level.

The EcoBalance model calculates total energy consumption (primary energy, kWh); consumption of building materials (tons of wood, concrete, other stone materials, metals, glass, oil and plastic products); consumption of fuels (tons of gasoline, diesel oil, fuel oil, coal, gas, peat, wood, etc.); production of emissions (tons of CO₂, CO, SO₂, NO_x, CH and particles; greenhouse gas emissions CO₂-eq. calculated from CO₂, CH₄ and N₂O); water consumption and waste-water production (m³); production of wastes (tons for recycling, compost, dump, etc.); total costs of construction, operation as well as transportation (euros). All these impacts of an area are evaluated during various phases of the life cycle: production, operation and transportation. Continuous impacts (operation and transportation) are evaluated



using, for instance, a period of 50 years. The output of the EcoBalance model consists of total and relative figures (for instance, kWh per square meter; CO₂ eq. tons per inhabitant) for each ecological dimension.

Examples of assessment results

The study covers in all 16 case study areas (36 alternatives) at residential area, municipality and regional levels in Finland. Examples of assessment results here focus on *residential area level*. Study areas have varying solutions with regard to location, structure, area density, housing types and heating systems, etc. The study areas are: four typical Finnish residential areas: a low density small house area, a compact small house area, a mixed area and an area with blocks of flats [7]; four rural “eco-villages”: Ekolehtilä, Pellesmäki, Puutosmäki and Vuonisolahti [10]; three new mixed areas: Ravirata [8], Hirssaari [9] and Länsi-Toppila [19].

Over a 50-year period residential areas require *energy* 400 – 1200 MWh per inhabitant (Figure 2). The production phase makes on average 13 % of the total energy consumption. Share of transportation varies between 6 % - 26 %. Most of energy consumption is due to heating and use of electricity. Transportation draws the greatest relative differences in energy consumption between areas. Energy is consumed most by rural “eco-villages”, because of relatively wide use of electricity for heating and as for transportation - long distances and the widespread use of private cars. The least energy is consumed by areas which have district heating and an efficient energy production system and which are located close to the city center, and walking and bicycling as well as public transport are widely utilized.

Greenhouse gas emissions account for 100 – 240 tons of CO₂-eq. per inhabitant over a 50-year period (Figure 3). The production phase is responsible for on average 11 % of greenhouse gas emissions. Share of transportation varies between 5 % - 38 %. Most of greenhouse gas emissions are due to heating and the use of electricity in buildings and they depend strongly on energy production systems. The use of wood heating decreases greenhouse gas emissions in rural “eco-villages”. Greenhouse gas emissions caused by transportation nevertheless eat away at the savings obtained by wood heating. Transportation draws the greatest relative differences between areas.

Residential areas require 100 – 400 tons of *raw materials* per inhabitant over a 50-year period (Figure 4). Of these, on average 60 % comprise building materials and 40 % fuels. Raw materials are required most in rural areas with scattered structure, which leads to a greater amount of infrastructure, as well as a relatively large amount of fuel used in heating and electricity consumption. Raw materials are required least in areas with compact structure and short distances.

The results of the case studies show that there are big differences in the ecological impact of different areas. Rural “eco-villages” are not necessarily very sound from an ecological point of view. On average, “eco-villages” require more energy and raw materials, they produce more emissions and they cost more than urban areas. One of the most important explanations for the differences is transportation, especially in the use of private cars. This is strongly

affected by the location of the area, the availability of public transport and individual preferences. Another important explanation for the differences lies in the consumption of heating energy, especially electricity.

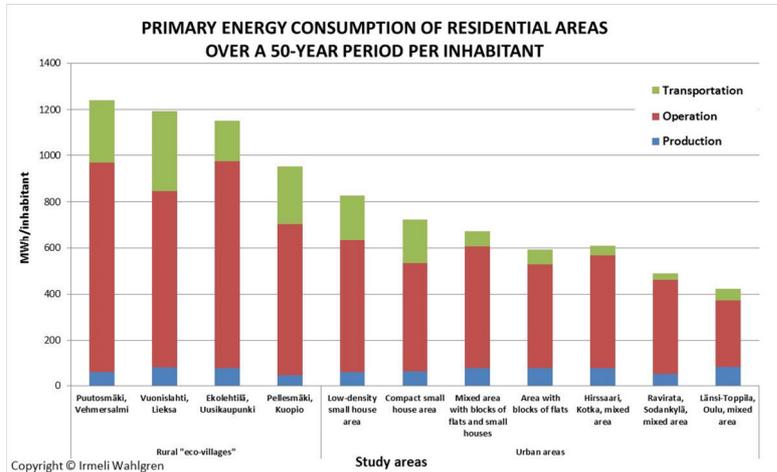


Figure 2. Primary energy consumption of residential areas over a 50-year period per inhabitant. Most energy is required in rural areas. [7 – 10], [19], [21 – 25], revised

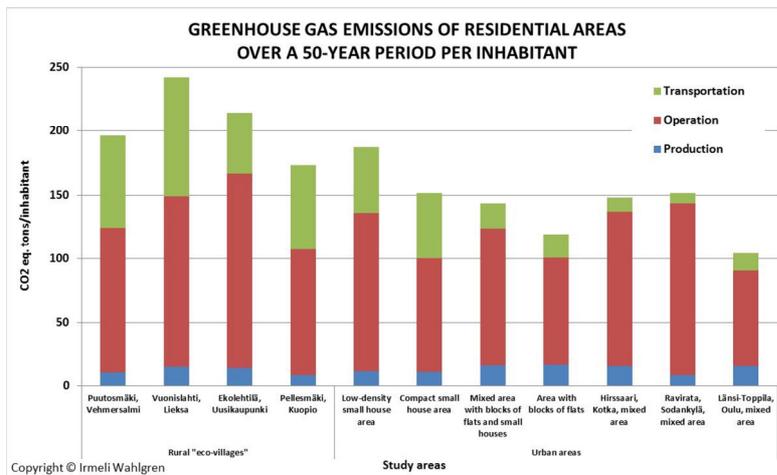


Figure 3. Greenhouse gas emissions of residential areas over a 50-year period per inhabitant. Emissions are produced most in rural areas and in low-density small house area. [7 – 10], [19], [21 – 25], revised

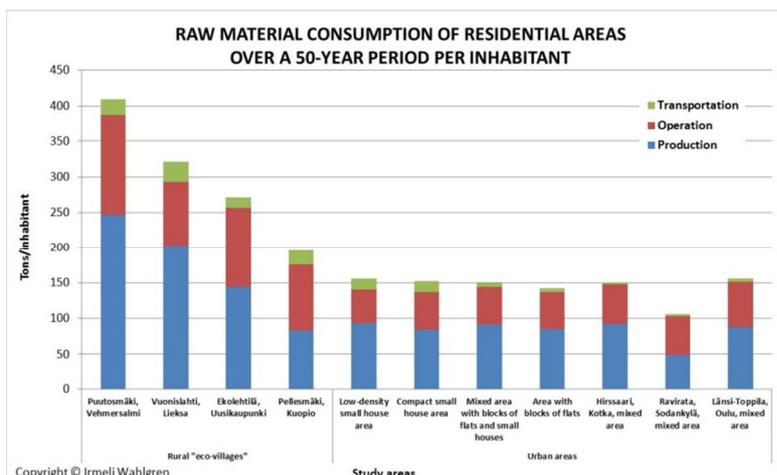


Figure 4. Raw material consumption of residential areas over a 50-year period per inhabitant. Raw materials are produced most in rural “eco-villages” and in the production phase. [7 – 10], [19], [21 – 25], revised

At municipality and regional levels differences in impacts are due to shares of infill development and dispersed settlement, area density and transportation and energy systems.

Important choices

Important choices in urban planning concern: the location of areas, distances, share of urban and rural development, complementary building / new areas, area density, structure – extent of networks, consumption of heating/cooling energy and electricity, heating system, energy production system, energy sources, building systems and materials, living space, transportation system, possibilities to walk and bicycle, availability of public transport (especially rail traffic) and the need for the use of private cars. Relations between greenhouse gas emissions and two important factors, area density and commuting distance, are presented in figure 5. The figure shows that it is important to avoid urban development based on very low densities, and that location is a very important factor when aspiring to minimize greenhouse gas emissions of urban form. Similar results are given considering other impacts: energy consumption, raw material consumption, other emissions and costs.

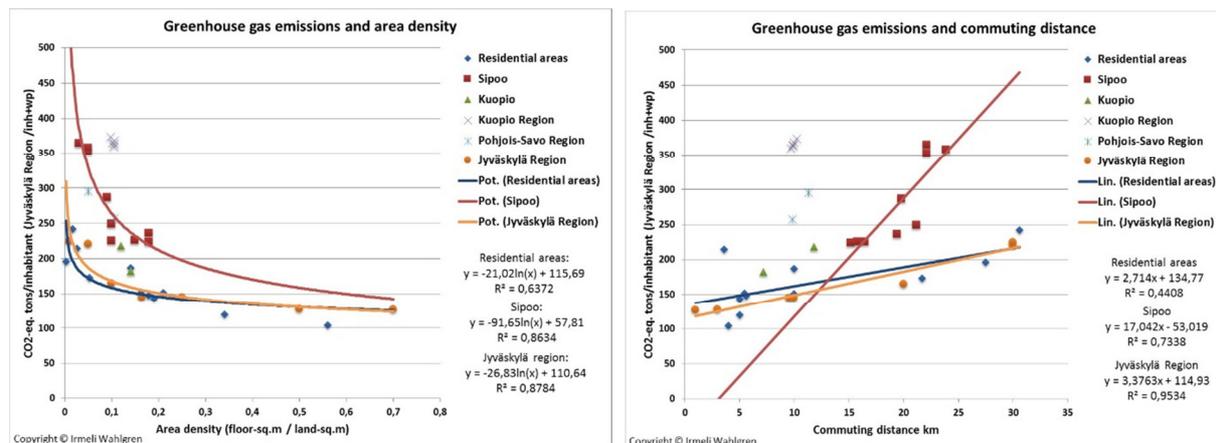


Figure 5. Greenhouse gas emissions and correlation between certain factors: on the left area density, on the right commuting distance. Different studies should not be compared to each others.

Discussion and conclusions

According to the research urban planning choices have large-scale significance for sustainable development of the built environment. The relative differences in impacts are biggest at detailed study levels. Decisions about location are, however, made at general planning levels. The research confirms that developing urban form more cohesive and compact and preventing urban sprawl are vital means when aspiring sustainable built environment.

The EcoBalance model can be used to assess impacts of varying urban and regional planning solutions and to compare planning alternatives on a life-cycle basis. Using the EcoBalance model has contributed municipalities and regional councils to carry out impact assessments of plans required by the law, and to make decisions on strategic land use planning. The model is



flexible and easy to modify according to assessment circumstances. It would be useful to develop the model from an expert tool to a tool for common use.

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Estimation of load and generation peaks in residential neighbourhoods with BIPV: bottom-up simulations vs. Velander

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Abstract: *In this paper a bottom-up approach is used to test the validity of the Velander method in estimating the load and generation coincidence factor of prosumers. Two case studies are used for the purpose: a typical single-family house in Scandinavian climate and a typical block of apartments in Mediterranean climate, both equipped with a BIPV (Building Integrated PV) system. Each case study is simulated for hundreds of units, each with different user behaviour inputs, building upon previous development and testing of such cases. This provides stochastic variability of the load profile, while variability of the generation profile is limited given the assumption that the units are located in the same neighbourhood. Results are presented and compared against estimations from the Velander method.*

Keywords: *Coincidence factor, BIPV, Neighbourhood, Velander's formula*

Introduction

Distributed generation at building level is expected to increase systematically and progressively in Europe, especially due to the requirement for all new buildings to be nearly zero-energy buildings (nZEB) by the end of 2020 (EPBD recast [1]). On-site electricity generation technologies available at building level – such as building integrated photovoltaic (BIPV) and micro-cogeneration, including fuel cells – will be deployed by building designers in new nZEB constructions as well as in refurbishment of existing buildings, especially as their investment cost decrease rapidly, as for PV. This large penetration of prosumers – buildings that both produce and consume electricity – will likely have an impact on the design and upgrade of distribution grids.

A distribution grid is traditionally planned according to the expected peak load, which determines how large power flows the grid components have to handle. Consolidated methods to size distribution grids are the Velander's formula and methods based on coincidence factors [2], [3], [4], [5]. These methods are regarded as reliable methods if the single loads are relatively homogeneous, e.g. all households, and the number of households is large enough, e.g. about 200 connections. Concerns exist on such methods' reliability for feeders serving smaller cluster, such as 20-60 households [5]. Furthermore, these approaches consider the grid as a one-way distributor of power to the customers, while the advent of a large number of prosumers will change this paradigm. Buildings will be, at times, net producers of electricity and will therefore export it to the grid, potentially challenging the grid's capacity limits.

Coincidence factor of peak load

There are several approaches to estimate the coincident peak load for a cluster of buildings, such as use of constant coincidence or simultaneity factors, the Velander's formula, and procedure based on statistical analysis [2], [3], [4], [5]. In the present study we focus on the Velander's formula, method first introduced in [6] and still widely used in Scandinavian countries, and on the criteria defined in the Spanish regulation [7] based on simultaneity factors.

The Velander's formula (1) uses the annual energy consumption of an average household to estimate the peak power demand, value used to size the electrical grid. The formula is:

$$P_{\max,n} = k_1 \cdot E \cdot n + k_2 \cdot \sqrt{E \cdot n} \quad (1)$$

where k_1 and k_2 are empirical coefficients, E is the reference value for the annual electricity consumption (kWh/y), n is the number of households and $P_{\max,n}$ is the peak power demand (kW) for n households. Table 1 shows typical values for the Velander coefficients for households as found in literature [3] and in the guidelines for planning of power grids in Norway [8]. Additionally, typical values of E for households can be found in [9], showing that a representative value for the last years may be set at approximately 16,500 kWh/(m²y).

Table 1 Values for Velander's coefficients.

Customer group	k_1 [h ⁻¹]	k_2 [(kW/h) ^{1/2}]
Typical domestic [3]:		
Without electrical heating	0.000330	0.0500
Cottage with electrical heating	0.000300	0.0250
Large house with electrical heating	0.000280	0.0250
In Norway [8]		
Single family house	0.000237	0.0119
Row house	0.000235	0.0116
Apartments block	0.000264	0.0140

The electric regulation of Spain [8] defines the peak power demand of a household or cluster of building with the equation (2), as the reference peak power for one household multiplied by the simultaneity factor.

$$P_{\max,n} = P_{\max,ref} \cdot SF(n) \quad (2)$$

Where $P_{\max,n}$ is the peak power demand over all households and $P_{\max,ref}$ is the reference peak power of each individual household. SF is the simultaneity factor, which depends on the number of households, as the Table 2 shows. Additionally, the same regulation sets the reference minimum requirement for distribution grids dimensioning at 5,750 W for residential buildings without electrical heating/cooling (9,200 W for those with).

Table 2 Simultaneity Factor (SF) depending on the number of households (n).

<i>n</i>	<i>SF</i>								
1	1	6	5.4	11	9.2	16	12.5	21	15.3
2	2	7	6.2	12	9.9	17	13.1	>21	15.3+(n-21)·0.5
3	3	8	7	13	10.6	18	13.7		
4	3.8	9	7.8	14	11.3	19	14.3		
5	4.6	10	8.5	15	11.9	20	14.8		

Case studies

In this paper a bottom-up approach is used to test the validity of the Velander's formula and simultaneity factors methods in estimating the load and generation peak power and coincidence factor of prosumers. Two case studies are used for the purpose: a typical single-family house in Scandinavian climate and a typical block of apartments in Mediterranean climate, both equipped with a BIPV system. Each case study is simulated for hundreds of units each with different user behaviour inputs, building upon previous development and testing of such cases [10], [11]. This provides stochastic variability of the load profile, while variability of the generation profile is limited given the assumption that the units are located in the same neighbourhood.

The Norwegian case study is based on a neighbourhood of 200 single family houses equipped with BIPV on the roof. The building envelope satisfy the requirements for the national definition of passive house, while space heating and hot water are supplied by an air-source heat pump as base system, with an electric resistance as top-up heater to cover peak loads. Therefore the houses are all-electric, since also cooking is electric. Hot water withdrawals and internal gains, such as occupancy, lighting and plug loads, are simulated with a stochastic user behaviour model as described in [10]; so that also the resulting space heating need is different from house to house, despite the identical envelope. The building load is simulated in 'Matlab' using quasi-steady-state according to EN norms, except for the hot water tank that is simulated with a fully dynamic model [10]. The average load for the entire neighbourhood is approximately 5,200 kWh/y per household, or 33 kWh/(m²y). The PV generation is simulated using the software tool 'PVsyst' and assuming some randomness in the orientation and tilt. Most of the houses (80%) are assumed to have a tilted roof, with an average tilt of 35°; here the orientation is assumed equally distributed between South and East/West. The remainder of the houses (20%) have a flat roof on which the PV system is mounted in arrays of 10° tilt and oriented either South/North or East/West, with equal probability. Each house has an installed capacity of 6.0 kWp, regardless of tilt and orientation. The average yearly yield from PV is ca. 5,300 kWh/y per household, so that the neighbourhood as a whole covers (and slightly exceeds) the entire energy demand of buildings, incl. lighting and plug loads. Hence, in terms of the EPBD definition (that does not incl. lighting and plug loads [1]) this is a plus energy neighbourhood.

The Mediterranean case study is based on a neighbourhood of block of apartments equipped with BIPV on the roof. The apartments are supplied with natural gas heating systems and without mechanical cooling system. Therefore, the electric load of the apartments comes from the appliances and the electric devices. The hourly energy simulation of the load is done by

the stochastic model integrated in 'TRNSYS' and the PV system generation is simulated using the software tool 'PVsyst'. For the load a stochastic model has been used. The model is based on a probabilistic approach and generates the individual consumption for each household, breakdown by the different equipment of the household. The model is able to reproduce the most important features of the residential electrical consumption, especially the particularities of the Mediterranean countries. For the simulation of the PV system, an installed capacity of 11.3 kWp per block (of 10 apartments) has been considered, assuming in all blocks an installation on flat roof with orientation 30° deviation from the south to the east (azimuth = - 30°) and tilt 33°. The same annual weather conditions are assumed for all the blocks, since the buildings are located in the same neighbourhood. In terms of primary energy balance, the PV system almost completely compensates in annual basis the gas consumption for the uses of heating and DHW, using conversion factors of 1.1 and 2.6 for gas and electricity. Hence, in terms of the EPBD definition [1] this is a nearly zero-energy neighbourhood.

Results and Discussion

Results from the simulations are shown in the following figures, where we represent peak power (whether load or generation peak) per household: $(P_{max,n})/(n)$. Simulation results are first obtained for the 200 households separately (i.e. 200 separate runs), with hourly resolution. In post processing, in order to investigate the effect of increasingly large aggregation of households, the results have been grouped by summing up load and generation from a random selection of households from the full set. For example, for the group of 10 households, 10 single households are chose randomly and their data series are summed up, hour by hour, for both load and PV generation. Since each single data set is stochastic, load and generation peaks from the subset will not be the same as the sum of the single households composing the subset. Furthermore, such grouping has been repeated 50 times per each subset, i.e. 50 different groups of 10 households have been created. In the following figures, all 50 data points are shown per each aggregation group (grey dots in the graph, vertically aligned). The aggregation follows a logarithmic scale, i.e. groups of 2, 3, 4... 10, 20, 30, 40... 100, 200, as shown in the x -axis.

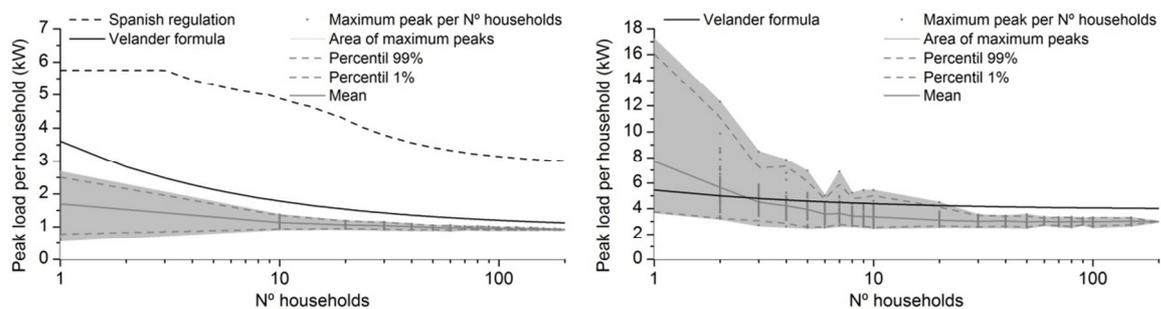


Figure 1 Peak load per household (y-axis) for increasing number of households considered (x-axis, logarithmic scale). Spanish case on the left; Norwegian case on the right. Velander's formula results in solid black line; Spanish regulation in dashed black line. Bottom-up stochastic simulation results in the grey area, showing data points, mean and 1st and 99th percentiles.



Figure 1 shows peak load per household, for increasing aggregation levels; Spanish case on the left, Norwegian on the right. For Spain, load peaks computed by simulation are always lower than the peaks predicted by the Velander's formula and by the Spanish regulation. Although, k_1 and k_2 coefficients used in the Velander's formula are taken directly from the literature and they are not specific for Spain, the shape of the curve is similar to the one obtained by simulation. However, the results taken from the Spanish regulation shows slight differences and they are more conservative in the sense that they predicts higher peak loads (5.75 kW and 3.6 kW for one house for the Spanish Regulation and Velander formula, respectively).

For Norway, load peaks computed by simulation are lower than the peaks predicted by the Velander's formula for aggregation of 30 households and more, while they are higher for aggregations up to 30. Also the shape of the curves is different, with the simulations showing a steeper curvature closer to the origin of the graph. The overlap between the grey area and the Velander line, as well as the different curvatures, is probably explained by the fact that the coefficients k_1 and k_2 from Table 1 are calibrated on the average Norwegian households electricity consumption, which is around 16,500 kWh/y (on a total of ca. 21-22,000 kWh/y), while the households in the case study have an average consumption around 5,200 kWh/y: less than a third. It is reasonable to expect that houses with such reduced demand have different relationship between yearly demand and maximum peak, especially considering that the performance of air-source heat pumps drops considerably in the coldest days (-20°C is the design temperature for Oslo), when the heating need is highest. Furthermore, these results are in line with the accepted notion that the Velander's formula is reliable only when the number of households is large [3], [4], [5]. However, for aggregation ≥ 30 households the peak load from the Velander's formula flattens at ca. 4 kW, while that from simulation flattens at ca. 3 kW. This might in part be the result of intentionally conservative calibration of k_1 and k_2 , and in part due to the low E of this case study.

The other aspect that must be taken into consideration is that the simulated stochastic values are based on an hourly method. The most widely used time resolution in building simulation and design is hourly, while higher time resolution models are still fairly uncommon. There can be substantial differences between hourly and sub-hourly data as indicated in [12] or [13], where for a house with electrical heating up to 69% difference is reported between hourly values and sub-hourly values (from 1 min to 5 min resolution). This leads to the conclusion that model for predicting load needs to be improved to better represent scenarios with a limited number of households (up to 30).

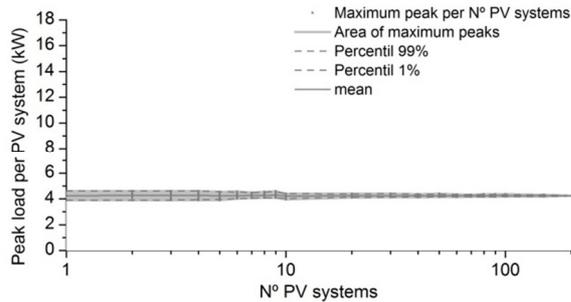


Figure 2 Peak generation per household (y-axis) for increasing number of households considered (x-axis, logarithmic scale). Norwegian case. Simulation results in the grey area, showing data points, mean and 1st and 99th percentiles.

Figure 2 shows the results for the BIPV generation, using the same end of scale as in Figure 1 for the Norwegian case. This is to highlight the fact that, despite some randomness introduced on the orientation and tilt of the PV installations, variability of generation is considerably limited compared to the variability of load. This is because the households are supposed to be in the same neighbourhood, so that when the sun shines it shines on all roofs. The generation peak at aggregated level is around 4.0 kW per household. For the Spanish case there is no variability, since all roofs are assumed to be flat and with an identical PV installation. The generation peak in this case is around 1.0 kW per household.

The generation multiple (GM) is described in [14] and it relates the size of the generation system to the maximum load. It can be calculated in terms of the ratio between peak generation and peak load, equation (3):

$$GM = \max[g(t)]/\max[l(t)] \quad (3)$$

where $g(t)$ stands for the on-site generation, i.e. PV for the two case studies in these paper, and $l(t)$ stands for the building loads. The value of GM in a purely 'consumer' building with no on-site generation would be equal to zero. In a 'prosumer' building, instead, GM value greater than one reflects that the generation peak power is higher than the load peak, and therefore indicates that there might be stress on the grid or that the distribution grid should be dimensioned based on the generation peak rather than the load peak. It should be noticed that calculating GM between generation and load represent the worst case. It is equivalent to assume that peak generation will happen when there is no load; and it compare it with the load peak that there would be in absence of generation, i.e. the standard 'consumer' building case.

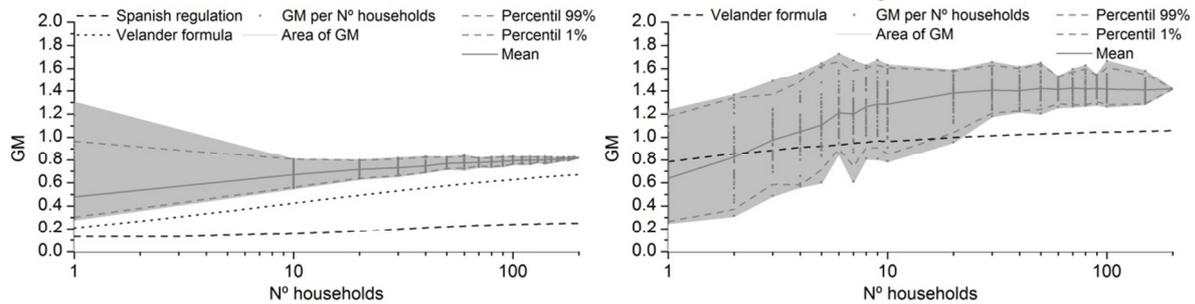


Figure 3 Generation Multiple per household (y-axis) for increasing number of households considered (x-axis, logarithmic scale). Spanish case on the left; Norwegian case on the right. Velander's formula results in dashed black line. Bottom-up stochastic simulation results in the grey area, showing data points, mean and 1st and 99th percentiles.

Analysis of graphs in Figure 3, values of GM shows an asymptotic behavior as the number of households in the neighborhood increases. In the case of the Spanish case study GM tends to a value below 1.0 due that primary energy balance is not equal to zero (i.e. relatively small PV installation). Being GM for the complete neighborhood below zero can drive to the conclusion that no reinforcement of the grid will be necessary if the grid was designed following the peaks values obtained from the simulation test. In the case, that the grid was designed to handle load peaks based on the Spanish regulation, having PV generation doesn't stress the grid in a significant way. For Norway, the GM from simulations tend to a value of ca. 1.4 while Velander's formula prediction flattens at slightly less than 1.1. This indicates that with very well insulated all-electric houses and large BIPV installations (that balance the entire annual demand) there might be stress on the distribution grid, also when this is dimensioned with the more conservative values from the Velander's formula.

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Sustainability Indicators for Building Modernization and Urban Renewal

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Abstract: *In Finland a large part of the building stock has reached the end of its design life and we have a concurrent demand for new housing in existing urban areas. We need replicable solutions for the renewal and infill development of our built environments. On European level, measures have been taken as to address current challenges. Finland is a bearer of responsibility with implemented national strategies for tackling climate change and building regulations for the energy performance of both new and existing buildings.*

Case examples highlight indicators like compactness, net land use, resource efficiency and an increased quality of life as characteristics of a sustainable development. Social regeneration and changed demographics can be key drivers for change. Sustainability assessments of best practice examples set benchmarks that can promote a clear set of sustainability measures for a wider stock of residential buildings and entire urban areas.

Refurbishment, sustainability indicators, Tes Energy Facade, urban renewal

1 Introduction

Finland has 2 836 000 dwellings [1], more than 570 000 of which are situated in concrete apartment buildings built in the late 1960's or early 1970's [2]. These have now reached the age of major renovations of building envelopes, water, heating and electricity supply systems. Energy efficiency is a growing concern: 84% of energy used in Finnish dwellings in 2008-2011 was used for heating, 29% of which was used in apartment buildings. [3] The regional perspective is climatic, based on long heating periods; urban, based on the volume of urban areas built between the 1960's and 1980's in the need of maintenance and repair; and industrial, with the need for replicable solutions for building repairs.

Our physical surroundings affect our quality of life. This was highlighted by the results of a survey of Finnish resident's opinions on their neighborhood in 2010 published by Strandell and commissioned by the Ministry of the Environment. The survey targeted areas dominated by multistorey apartment buildings. The results show that Finnish housing areas can be perceived as insecure, unclean, having a lack of natural environments, a bad image and size of buildings, unsatisfactory yards, and a low overall rating of the living environment. [4] Listed indicators relate directly to the quality of life: there exists a social need for urban renewal. Can the needs be met in a sustainable and cost efficient way? What are the key indicators to address and evaluate?



2 Sustainability Indicators for Urban Regeneration

2.1 European Perspective: Urban Challenges and Model Solutions

The challenges of European built environments are diverse and caused on one hand by urban decay and on the other by a continuous urbanization. In 2006, 75% of the Europeans lived in urban areas and it has been estimated that by 2020 the average will be 80%, and in some countries even above 90 %. Concurrently, the densification of our built environments has been defined as a common European target as to tackle the impacts of urban sprawl [5] i.e. an increased consumption of energy, land and soil, increased greenhouse gas emissions, air and noise pollution. An additional aim is to tackle the social polarization of suburbs.

The Finnish capital Helsinki provides one example of current challenges. Helsinki has grown at a speed comparable to south European cities like Porto, Portugal and Milan, Italy. When comparing low density areas, Helsinki is in a top position with close to 100% low density areas. [6] Helsinki represents typical fragmented Finnish urban structure and is one object for the application of current targets set by the Finnish Ministry of Environment: the compacting of Finnish cities, with the aim of integrating urban structures to decrease environmental impacts, improve the possibilities for efficient public transport and increase services. [7] Munich in Germany provides example of the opposite. It has been identified as an exemplary and desirable compact built environment. Even if the population has grown with 49% from 1955 to 1990, the town is defined as compact based on two indicators: built-up areas have grown slower than the population, and the share of continuous, dense residential areas add up to two thirds of all residential areas whereas only one third is defined as discontinuous. [8]

There have been efforts to redefine urban models driven by transport planners in response to urban sprawl. According to Transit-oriented development (TOD) models, the city is decentralized with alternative modes of mobility yet recomposed by walkable neighborhoods. Transportation needs to couple with decentralized water and sanitation systems and reduced car use, and promote a human scaled environment: compact, well-located, walkable and transit-served neighborhoods are critical to a sustainable future. In combination, TOD and green urbanism can deliver a powerful punch of energy self-sufficiency, zero-waste living, and sustainable mobility. [9] One example of such a development is Copenhagen, Denmark, that has developed in accordance with TOD since 1947. The linked town of Ørestad has been published as a successful development based on an assessment by Knowles in 2012, showing that e.g. car commuting has been exchanged for public transport. [10]

A different viewpoint is offered by the SmartCity - concept based on the use of smart grids and digital control systems coupled with information technology for real time energy management, transport systems and traffic management, water supplies, street lighting, high-tech manufacturing and data gathering. The aim is to reduce greenhouse gases and support energy efficient built environments by promoting the use of energy from renewable sources by scaling up innovation, heat and energy reuse, and retrofitting to “smart” houses. [11]



2.2 European Strategies for a Sustainable Development of Built Environments

On the European level, strategic measures have been taken as to address current challenges of and develop our built environments with the aim of a sustainable future.

In 2002 a roadmap was adopted for the development of the environmental policy-making in the EU during 2002-2012, the 6th Environment Action Programme. Four priority areas were identified: climate change, nature and biodiversity, environment and health, natural resources and waste [12]. It included a call for a Thematic Strategy on the Urban Environment with the objective of contributing to a better quality of life and with the emphasis on developing integrated urban areas, healthy living environments and a sustainable urban development. The strategy was adopted in 2006. [13] In 2011 the Roadmap to a Resource Efficient Europe followed that included two milestones directly relating to a sustainable urban development: (B) by 2020, EU policies are to take into account their direct and indirect impact on land use in the EU and globally, and the aim should be for no net land take by 2050. The roadmap includes targets concerning single buildings as well: (B) by 2020 the renovation and construction of buildings and infrastructure will be made to high resource efficiency levels. The Life-cycle approach will be widely applied; all new buildings will be nearly zero-energy and highly material efficient and policies for renovating the existing building stock will be in place so that it is cost-efficiently refurbished at a rate of 2% per year. 70% of non-hazardous construction and demolition waste will be recycled. [14] Economic and environmental issues have been tackled in the strategies through fostering the development of a green economy, energy and resource efficiency. The 7th Environment Action Programme entitled “Living well, within the limits of our planet” entered into force in January 2014 and guides European environment policy until 2020. [15] The emphasis is still on environmental aspects of sustainability. However, social aspects are noted in the targets as well. For example, “(T) the 7th EAP reflects the Union’s commitment to transforming itself into an inclusive green economy that secures growth and development, safeguards human health and well-being, provides decent jobs, reduces inequalities and invests in, and preserves biodiversity, including the ecosystem services it provides (natural capital), for its intrinsic value and for its essential contribution to human well-being and economic prosperity” [16].

In this context, Finland is a global actor and bearer of responsibility. A national Climate and Energy Strategy was compiled in November 2008. In 2009 the Finnish Government adopted the Foresight Report on Long-term Climate and Energy Policy, including the target of reducing greenhouse gas emissions by at least 80% by 2050, as compared to 1990 levels. [17] With regard to single buildings, building regulations applicable to new buildings with the emphasis on overall energy performance of a building came into force in June 2012 [18]. The Finnish statutory regulation on the improvement of energy efficiency of buildings undergoing renovation and alteration works applies to all building renovation works requiring a building permit since 01.09.2013 [19]. The aim is a decrease of the total energy consumption of buildings in Finland with 25 % and carbon dioxide emissions with 45% by 2050. Suggested means include systematic real estate upkeep. [20]



2.3 Case Studies

Single demonstration projects and urban scale pilots represent examples for the scalability and replication potential of sustainability strategies and implementations aiming at urban regeneration. Current aims for building works and resource efficiency in construction reflect ongoing developments in the field of sustainability, where a holistic approach is applied to projects and processes.

One example of large scale regeneration of an existing area is provided by the social housing demonstration in Roosendaal, the Netherlands realized in 2010-2011. The project included the refurbishment of in total 246 row house homes, 70 of which were renovated to passive house standard, and the addition of 100 new homes. [21] The demonstrated repair works comprised a retrofitting with timber facade and roof elements, triple glazed windows, the addition of ventilation units with heat recovery, a condensing gas boiler and solar thermal collectors. The energy efficiency targets included an 80% reduction in heating energy demand, a 50% reduction in hot water demand, and a 70% decrease in overall building related energy use. The building process utilized industrial prefabrication and assembly work was realized on site during one working day per apartment and with all building works done within a period of two weeks [22]. The alteration works were efficient, but a demanding part of the process was the preparation and implementation phases with the facing of habitants of various cultural and social background. The focus was on improving the quality of living and decrease costs for upkeep: not only for the building owner but for residents as well. [23]

On a community level the technological driven approach to sustainability should be balanced by a social approach. The Finnish context provides another example. In Finland, there is a significant volume of urban areas from between the 1960's and 1980's [24] in which a large part of the building stock has reached the end of its design life. Fulfilling the requirements for energy efficiency and repairs will require additional material effort with higher embodied impacts. The effort will be higher than the gains of urban mining, and the cost of financing the process cannot be carried by the residents alone. Due to the speed and scale at which these areas were built, the demographics of the areas are fairly homogenous, and social needs are consistent. Typical in Finland is the need to improve safety and accessibility with lifts added to residential buildings, and to rework and reprogram dilapidated shopping centers which no longer meet current retail needs or the service needs of an ageing population. [25] Out of the economic framework is how local municipalities can reduce growing health care and frail care costs, by subsidizing the investment cost for home renovations. If the location of the area has potential for infill and a demand for expansion, then the investments can be better distributed so long as the land ownership, property legalities and the public planning process can be resolved. In this context, social sustainability is also an economic challenge. The City of Kouvola is one Finnish example of a town that has developed a 2030 - strategy for the infill development of central areas aiming at improving the quality of the environment, increasing the amount of available housing for families and increasing services. The plan for infill includes both new building and the addition of storeys to existing buildings. [26]



For institutional owners a wish for social regeneration can be a key driver for investments. Where the demographics of a residential area have become skewed, or a target market for residential building requires radical changes, the owner is prepared to invest in redefining the profile of the end users and buildings. One example of a target market driven retrofit process is the refurbishment site in Oulu, Finland realized in 2012-2013 as a demonstration in project E2ReBuild. The building is one of five student apartment buildings in a housing corporation completed in 1985. The aim was for a comprehensive refurbishment of both indoor spaces and the building envelope implementing TES Energy Façade. The target was for energy efficiency at passive house level and modernized flats that would attract today's students with families. [27] The main driver for the retrofit was the change in markets: modern students no longer enjoy living in single apartments. Instead, apartments were changed into modern, energy efficient and smart student family homes including upgraded outdoor facilities.

In some cases of social housing, the resident population has no alternative but to remain in the area that is being upgraded. The owners need to sell the residents the benefits of energy efficiency and sustainability, in order to trade off the increased rental costs with the perceived benefits. A careful cost effective energy renovation may be limited to the reuse of heating and installation of building automation, which has a realistic payback period. This is typical of an engineering approach to energy cost optimization, but requires tradeoffs with the residents, for example kitchen and bathroom renovations, for the disturbances to be accepted by tenants.

3 Discussion, Conclusion and Acknowledgements

3.1 Discussion and Conclusion

Key sustainability indicators with regard to building modernization and urban scale renewal rely firmly on all the three aspects of environmental, economic and social sustainability.

National strategies, research and implementations on the scale of demonstration sites support the European commitments to a low-carbon economy, a resource efficient future, a smart, sustainable and inclusive growth with regard to urban renewal. On single building level the aims are enforced through requirements for energy performance of both new buildings and buildings undergoing major renovations [28]. A striving for urban densification, renewal and social well-being can be identified. On strategy level, these are key indicators.

A sustainable land use and management is at the center of current aims for European urban environments and the discussed cases also suggest indicators like compactness and net land use as characteristics of a sustainable urban development. Land use becomes critical in regions like the Alpines where areas available for permanent settlement are limited [29].

Resource efficiency is a strategic goal and economic target for the construction sector including new building, refurbishments and urban structures. In realized demonstrations the focus has been on replicability and reducing the environmental impacts of repairs through the

use of life cycle based products, such as TES Energy Facade. Sustainability assessments of best practice examples set benchmarks that can be used to promote a set of sustainability measures for a wider stock of residential buildings and entire urban areas.

Economics are decisive for the investor. Retrofit methods such as TES Energy Façade may anticipate future requirements for environmental considerations but there are no mechanisms to receive compensation for reducing greenhouse gases associated with the material flows of retrofits. Neither are the economic benefits of energy efficiency reflected in short term investments, and property values do not reflect their life cycle costs. The economic incentive for deep refurbishment, infill development and the regeneration of built areas has to be found in increased income resulting from e.g. a raised standard of living, increased let area or savings in upkeep costs. Based on selected cases a need for social regeneration and changed demographics might also be key drivers for investments and indicators for change. An increased quality of life is a desirable future and benefits all on both building and urban scale.

3.2 Acknowledgements

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Session 106:

Which are the most notable contributions to applying LCA in building renovation?

Chairperson:

Charlotte Valdieu, Catherine

Sustainable Urban Development European Network (SUDEN), France

Methodology proposal for the life cycle sustainability assessment applied to retrofitting in a local context

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Abstract: *In the European context of upgrading the housing stock energy performance, multiple barriers hinder the wide uptake of sustainable retrofitting practices. Moreover, some of these may imply negative effects often disregarded. Policy makers need to identify how to increase and improve retrofitting practices from the comprehensive point of view of sustainability. None of the existing assessment tools addresses all the issues relevant for sustainable development in a local situation from a life cycle perspective.*

Life cycle sustainability assessment methodology, or LCSA, analyzes environmental and socioeconomic impacts. The environmental part is quite developed, but the socioeconomic aspect is still challenging. This work proposes socioeconomic criteria to be included in a LCSA to assess retrofitting works in the specific context of Brussels-Capital Region. LCSA feasibility and challenging methodology aspects are discussed.

Keywords: housing, retrofitting, life cycle sustainability assessment, LCSA, health

Introduction

The large amount of energy-upgrading retrofitting processes currently taking place in Europe may entail negative effects barely considered in decision making (unexpected impacts on health, fabric performance, economic accessibility to works, cultural value, etc. [1]). Some of the barriers for the uptake of “more sustainable” retrofitting practices (with the best environmental and socioeconomic performance) are: the fact that regulations and policies in the building sector mainly focus the reduction of energy consumption and emissions¹, high investment costs that often determine decisions, complexity of considering all the economic, environmental and social factors involved in decision making, as well as the lack of reliable available information about social performance.

Available tools for the assessment of sustainability in buildings such as labels or rating systems were originally created to assess environmental impacts mainly focusing the use phase. The life cycle perspective is increasingly being included: environmental life cycle assessments are encouraged, or even required (e.g. LEED, CASBEE); socioeconomic factors are also being added, although not covering yet all the life stages, and context specific issues are not addressed. Rating systems are based on scoring scales and weighting, but impacts on all the dimensions of sustainability are not calculated, and weighting is based on expert agreement rather than on effects on sustainability.

The environmental life cycle assessment methodology (e-LCA, or LCA) has been largely developed and applied; life cycle costing (LCC) too, but often neglecting some of the life

¹ EPBD 2010 Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast).



cycle stages and externalities; and the social assessment (s-LCA) is still very recent. These methodologies overlap in some of the impacts considered (health is addressed by e-LCA and s-LCA, social well-being and dignity by LCC and s-LCA. Indeed, LCC as one of the branches of sustainability has been questioned by Jørgensen et al [2]. Life cycle sustainability assessment (LCSA) integrates these three methodologies [3]. Although still challenging due to the different state of development of the three methodologies, it seems suitable to work towards this integrated approach [4], since focusing the three techniques separately might imply impact shifting between sustainability dimensions, and the consequent misuse of the term sustainability.

Approach

The final goal of this research is to develop LCSA methodology to be applied to housing retrofitting in Brussels-Capital region. Since the methodology is highly developed for the environmental issues, the focus is on the implementation of socioeconomic criteria. Our methodology approach is presented below, following the structure of life cycle analyses: goal and scope, life cycle inventory (LCI), life cycle impact assessment (LCIA) and interpretation of results

Goal and scope: since socioeconomic assessment is highly context related [5], criteria to be considered must be specifically defined depending on the application. This development focuses decision makers in Brussels-Capital Region: to prioritize retrofitting solutions to be encouraged (by means of economic incentives, dissemination, etc.), to optimize enhancement instruments (how much would be suitable to be invested), to identify opportunities for more sustainable practices, etc.

The life cycle inventory (LCI) consists in collecting all the inputs and outputs throughout the whole life cycle having an influence on the assessed impacts. In a LCSA, the type of data to collect is diverse, related with energy flows, use of materials, economic flows, social performance, etc. For socioeconomic issues, appropriate inventory indicators must be specifically selected and defined. Our approach consists in: (1) transferring the applicable criteria proposed by the main reference documents (Guidelines² [5], EN 15643-3³, rating systems⁴ and research projects⁵) into inventory indicators; (2) adapting those indicators to housing retrofit; (3) developing new indicators to address missing context-specific socioeconomic issues. The resulting proposal is presented in next section.

The impact assessment stage (LCIA) analyzes impacts produced by inventory indicators. EN 15978:2012 standardizes environmental impact categories and methods. But socioeconomic impact categories are not standardized, nor the methods of assessment. Nor does the life cycle

² Guidelines for social life cycle assessment of products and The Methodological Sheets for Subcategories in Social Life Cycle Assessment

³ EN 15643-3:2012 Assessment of buildings - Part 3: Framework for the assessment of social performance

⁴ LEED, BREEAM, Valideo

⁵ Superbuildings <http://cic.vtt.fi/superbuildings/>, OpenHouse <http://www.openhouse-fp7.eu/>

initiative⁶ propose methods for social impact assessment. Indeed, this initiative recognizes the feasibility of the classification step (to assign impact categories to the inventory data), but recommends not to aggregate or weight results of the three methodologies (environmental, social, economic), due to the early stage of LCSA [3].

Possible approaches are presented by Parent et al [6]: the **socioeconomic relative performance approach** (also called Taskforce’s or Type 1) consists of inventory indicators scoring according to reference points (best and worst performance), aggregation, and weighting. Scoring can be done related to a reference scale, and weighting can be based on multiple criteria, such as expert panel advise, monetization, etc.; the **characterization approach** models—for those indicators for which a cause-effect relation exists—the impact pathway, by defining impact indicators, units to quantify them and characterization factors to relate inventory indicators with midpoint and potentially endpoint impacts (Figure 1).

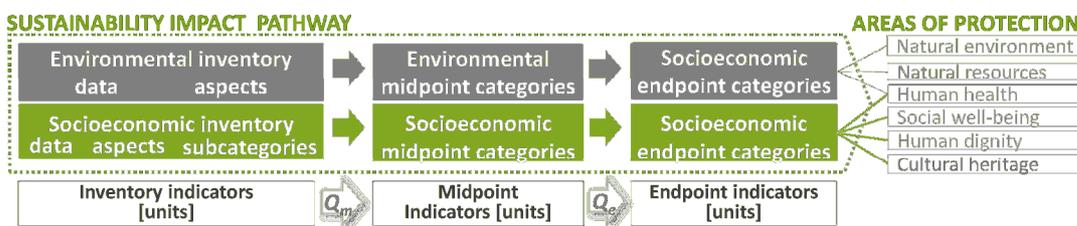


Figure 1. Impact pathway structure and terminology in LCSA. (*Q*: characterization factors)

The first approach is followed by most building assessment tools. Despite some challenging points (such as the min.-max. reference point definition, or the integration with environmental LCA in a comprehensive assessment), the application is feasible to date. It allows benchmarking socioeconomic performances, to identify opportunities to improve sustainability of a product, service, etc. The characterization model is the similar approach to environmental LCA. This is still challenging due to the lack of evidences between some of the criteria and associated impacts [7]. Although very recent and scarcely applied, interesting approaches exist focusing some of the impact categories, such as Weidema’s and Hunkeler’s approach, as presented by Parent [6]. In next section, we analyze the feasibility for analyzing impacts on health related to housing retrofitting.

The interpretation of results for the first approach as a “combined” way of reading—as proposed by the life cycle initiative [4]—seems not obvious. Results might be opposite for environmental and social performance, and interpretation rely on identifying opportunities for improvements. By following the characterization model approach, results must be interpreted very carefully, considering data reliability and strength of cause-effect relationship.

Methodology proposal

Goal and scope: in this case, comparisons and conclusions can only be made between similar housing models: similar typology (distribution and construction type), management (social or

⁶ UNEP/SETAC life cycle initiative <http://www.lifecycleinitiative.org/es/>

private housing), tenancy (ownership, co-ownership, or renting), heritage value, conditions before works, etc.

The socioeconomic inventory assessment (LCI) follows the approach presented in the previous section. Figure 2 shows the inventory indicators proposed, with some examples of the data involved, classified by items, aspects and subcategories, as well as the assigned impact categories.

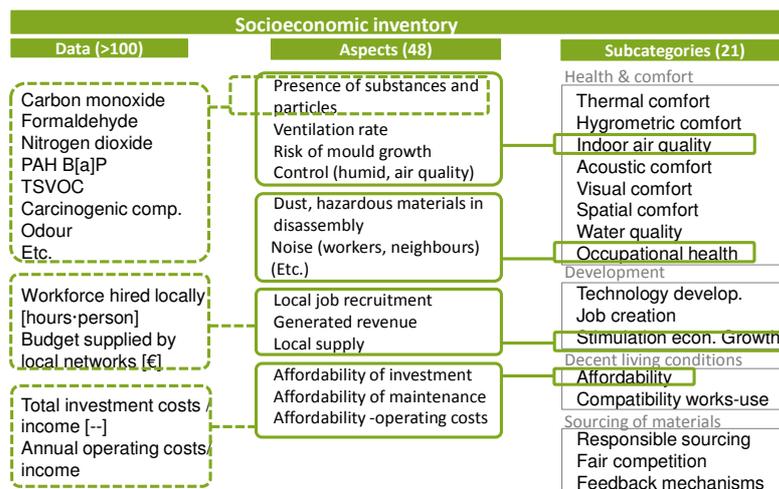


Figure 2. Some examples of socioeconomic inventory, classified by data, aspects and subcategories

Indicators related with accessibility, adaptability, and safety and security, have been transferred from EN 15643-3, and prEN 16309⁷; most criteria related with the responsible sourcing of materials and services have been transferred from the Guidelines; in order to address health and comfort, EN 15643-3 proposal has been completed with other assessment tools and research projects.

In order to address the poor housing conditions, unaffordable investment costs of retrofitting, fuel poverty rates and damaged construction sector, indicators have been proposed to assess affordability of investment, maintenance and operating costs, job creation and local supply, as well as deteriorated working conditions, social dumping, or qualified labour shortage.

Indicators are lacking to characterize cultural value (heritage and architectural quality of new interventions). In Brussels, pre-war housing has been largely studied, although evaluations seem to be case-by-case analyses rather than a standard indicator-based methodology. Post-war housing stock is still challenging.

For the impact assessment stage (LCIA), the objective is to cover all the sustainability issues, the so called “areas of protection”. The six considered in this work are: natural resources⁸, natural environment⁸, human health⁸, social well-being⁹, human dignity⁹ and cultural

⁷ Draft prEN 16309 Sustainability of construction works – Assessment of social performance of buildings – Methods (or methodology)

⁸ Largely accepted in e-LCA

⁹ Proposed by Weidema [8]

heritage¹⁰. Impact pathways between the object of assessment and the areas of protection are classified in inventory indicators, midpoint, and endpoint impact categories (Figure 1).

Bearing in mind the aim towards a comprehensive sustainability analysis, it seems reasonable to develop socioeconomic assessment by following the same approach than e-LCA (characterization model approach). We analyze in this work the feasibility of modeling the impact pathway for human health related to housing retrofitting. Figure 3 shows the contributors to human health: environmental health, occupational health, and health of building users.

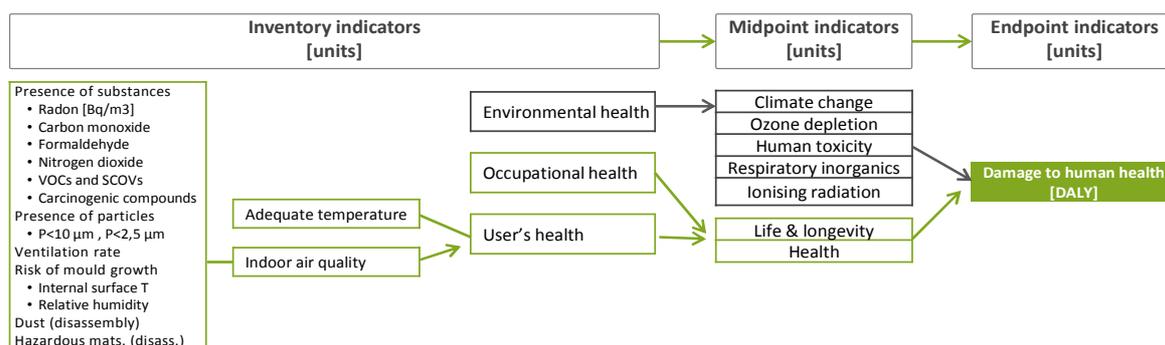


Figure 3. Contributors to health related to retrofitting

The analysis of impacts on **environmental health** is covered by e-LCA. Life cycle stages involved are the supply chain of building products employed in renovation (production and transport), disposal of replaced elements, energy consumed along the remaining life of the building, and final end of life. The inventory analysis is challenging due to the lack of building-specific information in environmental databases (such as Ecoinvent), and the complexity due to the large amount of items involved. Calculation methods define characterization factors.

Occupational health is related with workers involved along the supply chain, workers at site and disposal. For the background processes, available data about working conditions (accident and disease rates, living conditions, etc.) are available by type of works, sector and country¹¹. The level of aggregation is too high to differentiate two options for retrofitting included in the same activity in the same country, but makes possible to assign potential impacts depending on the country of origin. In this topic, Weidema has provided estimates of health consequences per unit process [8].

Negative effects on **user's health** are mainly related to inadequate temperatures, and to indoor air quality (including mould, concentration of substances and particles, etc.) [1]. Although the concept might vary depending on the country, the term “fuel poverty” defines the household inability to keep the home adequately warm at an affordable cost, as a result of low household income, poor heating and insulation standards, and high energy prices.

¹⁰ Life cycle initiative

¹¹ In sources such as reports of international organizations (ILO, WHO), and in the recent SHDB Social hotspot database <http://socialhotspot.org/>



Indicators of fuel poverty include being in arrears with energy bills, being unable to pay to maintain one's home at an adequate temperature, and having dampness and/or mould in one's home (EPEE¹²). The high costs of retrofitting, added to increasing fuel prices may increase the current fuel poverty rates, and consequent effects on health. Although the link between inadequate temperatures indoors and mortality increase is admitted by the WHO, there is still a lack of evidence about direct effects for pathway modeling, and more research is needed.

Air-tightness improvement and the installation of ventilation mechanisms with heat recovery, might imply indoor pollutant concentrations higher than usual exposures in dwellings before retrofitting. Studies performed in the UK show relations between health and strategies of fabric insulation, ventilation, fuel switching and behavioral changes, by defining pathways for modeling the effects of concentration of pollutants (Radon, smoke, and dampness and mould¹³). These studies highlighted the potential very high levels of PM_{2,5} exposure [9]. VOC concentrations were excluded due to the lack of reliable evidences.

Research has been done last years to model indoor toxicity. Models are based on Hellweg's [10], considering of material emission rate, ventilation rate and intake fraction. Recent results show that impacts on health due to finishing materials toxicity are in cases one order of magnitude higher than impacts due to air quality outdoors [11]; therefore, these cannot be disregarded anymore. The availability of information about the emission rate of materials is a main gap to solve.

Conclusions

This methodology presents an approach towards LCSA of housing retrofitting in a local context. The inventory assessment in this document proposes the relevant socioeconomic issues to be included beside the environmental ones.

Work must still be done to enable the modeling of human health pathways: to provide less aggregated data about occupational health in the region, to improve knowledge for modeling toxicity in workplaces and housing, as well as providing information about material emission. The areas of protection "human dignity" and "cultural heritage" are still in an earlier state. For these, it seems feasible, to date, to follow the "relative performance approach", and to benchmark options by assessing impacts on a scoring scale basis.

Next steps will tackle the feasibility to assess impacts of different retrofitting works on prosperity, as well as applying the methodology to case studies: energy upgrading works including system update and fabric performance improvement. The goal of the application is to test the feasibility of the methodology, as well as to compare possible options (repercussions of using "conventional" or "natural" materials, different energy-upgrading levels, etc.)

¹² IEE research project. European fuel poverty and energy efficiency <http://www.fuel-poverty.org>

¹³ based on empirical and building physic models, calculated with adaptation of Comparative Risk Assessment method by means of an adaptation of "Comparative Risk Assessment" used by the WHO for the global burden of disease



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Life cycle optimized application of renewable raw materials for retrofitting measures

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Abstract: *When retrofit measures are planned, apart from the costs, the difficulties usually lie in the wide decision space. This paper introduces a method for a systematic life cycle investigation in the ample leeway that retrofitting measures give. Using the example of a single family house the analysis illustrates how CO₂-savings and their costs are influenced by particular factors, such as heating system, feasible insulation thickness and applicable material. The solutions rank according to several criteria, including life cycle cost, life cycle environmental impact and CO₂ abatement cost. Since such an extended study is not feasible for every retrofit measure, we developed an optimization method which uses evolutionary algorithms. The application in a case study proves that the method is able to find the cost-optimal level of the retrofit measures, under consideration of the determining factors. This contributes to reduce the environmental impact of the building stock in the most efficient way and to increase the application of renewable raw materials.*

Life Cycle Assessment, renewable raw material, energy efficient façade retrofitting, optimization, evolutionary algorithms

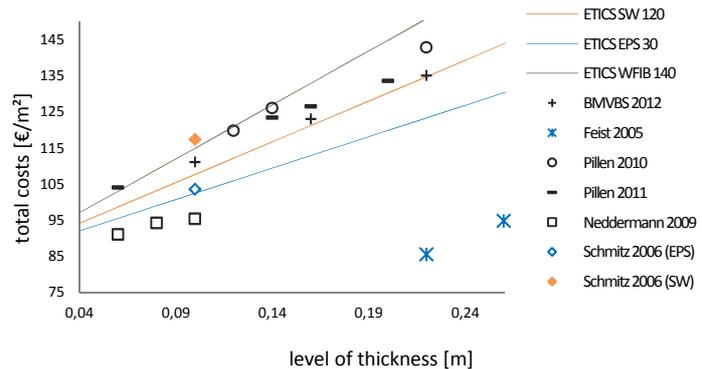
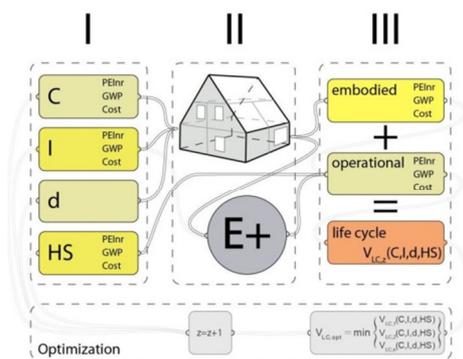
Introduction

Determining the cost-optimal solutions for CO₂-reducing requirements in the building sector is one of the challenges left, on the road to a low carbon economy. The difficulties in defining building energy standards at optimal cost level are widely discussed in [1], [2]. Especially for defining future standards of energy efficient refurbishment, the public acceptance of the proposed measures might be more important than its effects [3]. To raise the stagnating renovation rate and to decrease the environmental impact of the building stock a reliable prediction of estimated life cycle costs and cost efficiency is necessary. One difficulty lies in the availability of realistic input data. Even more problematic is the limited consideration of variants for building envelope, equipment and framework conditions that leaves considerable CO₂-saving capabilities unexploited. In order to reduce the energy demand, to increase the proportion of renewable resources, and to use fossil resources as efficient as possible, it is important to investigate a possible cost-neutral use of renewable, carbon sequestering materials for retrofit measures as suggested in [4]. This requires reliable data bases and very quick multi-criteria analysis methods. These must be able to analyse a great amount of variants in order to find the most efficient solutions considering the entire life cycle.

Concept

The evaluation method for the life cycle of retrofit measures which is presented here consists of three main steps (see Figure 1). First of all, four variable parameters for the retrofitting measure have to be defined: the heating system (HS), the construction (C), the insulation material (I) and the thickness of insulation (d). For each of the above mentioned components (HS, I and C) we need data to describe their physical, ecological and economical characteristics. Secondly, an automatic mass survey is carried out. The multiplication with the specific data leads to the embodied effort needed, whether it is environmental impact, primary energy or invested cost. Simultaneously a thermal simulation is performed by *EnergyPlus* (*E+*) to compute the heating demand. Based on this heating demand, the operational effort is calculated and provided in data for primary energy, environmental impact and costs. In the third step, operational effort and embodied effort are added, according to the chosen assessment period. This indicates the life cycle effort for one possible retrofit variant. Here it is given out for the life cycle non-renewable primary energy ($PE_{nr,lc}$), the life cycle global warming potential (GWP_{lc}) and the life cycle costs ($Cost_{lc}$).

For the implementation of the method we chose *Grasshopper3D*, a graphical algorithm software. The geometrical model of the original house is imported into *Rhinoceros* and linked with *Grasshopper3D*. The simulation software *E+* is connected to *Grasshopper3D* with a plug-in called *Archsim*. For the data – including cost, physical data and environmental impact – we developed a text-based import method for *Grasshopper3D*. The great advantage of this approach is the complete parametric input that allows a quick adaption to changes in data or geometry. Furthermore, it makes the use of evolutionary algorithms possible.



Framework and Data bases

There is a number of existing databanks for specific environmental data for materials and energy carriers. We used the data, provided by the Swiss KBOB [5], which are based on *ecoinvent 2.0*. The calculation of construction investment cost bases on parametrical values for construction and insulation material which refer to market-based analyses. To validate the results of our cost calculation method, we compared it to data from relevant literature. Construction costs taken from older studies were adjusted to current building price indices.



This provides a reliable database for the calculation of the total investment cost, as shown in Figure 2. Nevertheless, an uncertainty remains in the estimation and calculation of construction costs and it may influence the results considerably. Evaluating different methods of cost estimations, Ruf [6] shows that even detailed execution-based calculation methods may have deviations of up to 10% from the real costs. This is supported by the study of BMVBS [7] at 2012, which determined a cost function for External Thermal Insulation Composite System (ETICS) by analysing 531 retrofit projects. This study shows significantly scattering values with low correlation to parameters that are expected to have a bearing, such as insulation thickness. The parametric cost function used here shows sufficient compliance with the results of BMVBS [7], as shown in Figure 2, and furthermore it enables variations of material and construction. The physical material data are based on values taken from literature or provided by producers. Based on technical approvals we created a matrix suggesting valid combinations of materials and construction.

Table 1: GWP, PEnr and Cost of insulation materials and constructions

insulation	λ_i W/mK	c J/kg K	PEnr (MJ/m ³)	GWP (kg/m ³)	Cost €/m ³	construction	ELS a	Δ PEnr MJ/m ²	PEnr'(d) MJ/m ³	Δ GWP kg/m ²	GWP'(d) kg/m ³	Cost €/m ²	Cost(d) €/m ³
GW 30 kg/m ³	0,035	810	1373,4	45,2	88,00	Interior Insulation VB	30	83.09	64.92	5.04	3.12	55.00	28.00
GW 50 kg/m ³	0,032	810	2289,0	75,3	152,00	Interior Insulation CA	30	136.95	0.00	6.60		70.00	
GW 100 kg/m ³	0,035	810	4578,0	150,6	285,00	ETICS	30	240.00	0.00	11.00		85.00	
SW 40 kg/m ³	0,035	1030	760,0	52,0	143,80	VF wood cladding, wood substructure	40	17.69	64.92	0.75	3.12	100.00	28.00
SW 50 kg/m ³	0,400	1030	1520,0	104,0	269,00	VF fibre cement cladding, alu substruct.	40	252.04	1766.00	21.22	2084.88	115.00	20.00
SW 100 kg/m ³	0,036	1030	1824,0	124,8	226,00	DBCW	60	495.00	0.00	59.00	0.00	135.00	
SW 34 kg/m ³	0,036	1030	2280,0	156,0	196,50	abbreviations							
EPS 15 kg/m ³	0,038	1400	1580,0	110,4	112,00	GW	glass wool	VB	vapour barrier				
EPS 30 kg/m ³	0,035	1500	3160,1	220,9	174,00	SW	stone wool	CA	capillary active				
PUR 30 kg/m ³	0,027	1480	3040,2	203,6	250,00	EPS	expanded polystyrol	ETICS	exterior thermal insulation composite systems				
WFIB 50 kg/ m ³	0,039	2100	548,2	21,6	150,00	PUR	polyurethane foam	VF	ventilated façades				
WFIB 110 kg/ m ³	0,040	2100	1206,1	47,5	272,00	WFIB	wood fibre insulation board	DBCW	double brick cavity wall				
WFIB 140 kg/m ³	0,043	2100	1535,1	60,4	299,00	CE	cellulose insulation						
WFIB 190 kg/m ³	0,045	2100	1973,7	77,7	410,00	CS	calcium-silicate slabs	ELS	estimated life span				
CE 50 kg/m ³	0,040	2150	371,5	19,6	100,00	HE	hemp fibre mats	GWP	global warming potential (CO2 equivalent)				
CS 115 kg/m ³	0,046	1300	394,8	48,4	339,00	VIP	vacuum insulation panels	PEnr	primary energy non renewable				
HE	0,040	1600	632,0	3,1	170,00	PF	phenolic foam board						
VIP	0,007	800	13500,0	744,0	7500,00	indices							
PF	0,023	1400	4936,4	260,3	335,00	c	construction	e	embodied	inv	invest		
						i	insulation	o	operational	cap	(annualised) capital		
						hs	heating system	lc	life cycle	main	maintenance		

Calculation

The embodied environmental impact of the chosen construction and insulation is computed referring to a mass survey ($GWP_{e,c}$, $GWP_{e,i}$, $PEnr_{e,c}$, $PEnr_{e,i}$). Investment costs for insulation and construction are calculated analogously. In case of an upgraded heating system the investment costs of it ($Cost_{inv,hs}$) have to be added. The embodied impact of the heating equipment is not taken into account because reliable data availability is critical. The annual capital cost ($Cost_{cap}$) of total investment is calculated by means of an annuity factor. The embodied effort is summed up with the operational effort which is determined by the heating demand and the efficiency of the heating system (GWP_o , $PEnr_o$). Additionally, the energy costs ($Cost_{energy}$) are calculated according to the determined energy prices. For improved heating systems additional maintenance costs ($Cost_{main,hs}$) of 1.5% of $Cost_{inv,hs}$ are assumed. At the microeconomic level (view of end-user) we compare the total life cycle cost of a retrofitting variant n ($Cost_{lc,z} = Cost_{cap,z} + Cost_{main,hs,z} + Cost_{energy,z}$) to the total life cycle costs of the existing building ($Cost_{lc,0} = Cost_{energy,0}$) over the whole assessment period. The maximum of CO₂ reduction in relation to necessary investment costs is of interest at the macroeconomic level. The cost efficiency of CO₂-saving measures can be expressed by CO₂

abatement costs (€/t CO₂-equivalent), considering the ratio of total investment cost ($Cost_{inv}$) and GWP , saved over the entire life cycle ($GWP_{lc, saved}$).

Table 2: Input and output values

embodied				operational	life cycle efforts of variant	life cycle efforts of basic scenario	savings achieved	specific values for fitness function	
measure	Heating System	total							
$PEnr_{r,c}$	$PEnr_{r,i}$		$PEnr_r$	$PEnr_o$	$PEnr_{lc}$	$PEnr_{lc,0}$	$PEnr_{lc, saved}$	$Cost_{inv}/PEnr_{lc, saved}$	$Cost_{lc}/PEnr_{lc, saved}$
$GWP_{r,c}$	$GWP_{r,i}$		GWP_r	GWP_o	GWP_{lc}	$GWP_{lc,0}$	$GWP_{lc, saved}$	$Cost_{inv}/GWP_{lc, saved}$	$Cost_{lc}/GWP_{lc, saved}$
$Cost_{inv,c}$	$Cost_{inv,i}$	$Cost_{inv,HS}$	$Cost_{inv}$	$Cost_o$	$Cost_{lc}$	$Cost_{lc,0}$	$Cost_{lc, saved}$	$Cost_{lc, saved}/Cost_{inv}$	
			$Cost_{cap}$	$Cost_{main}$					

Case study

For this paper we took a typical single-family home in Germany from the 1960s as a reference building. Thermal analyses for this building have been carried out with the aid of various programs [8]. They serve as verifications for the simulation results. In the simulation we operated with framework conditions as they are shown in Figure 3.

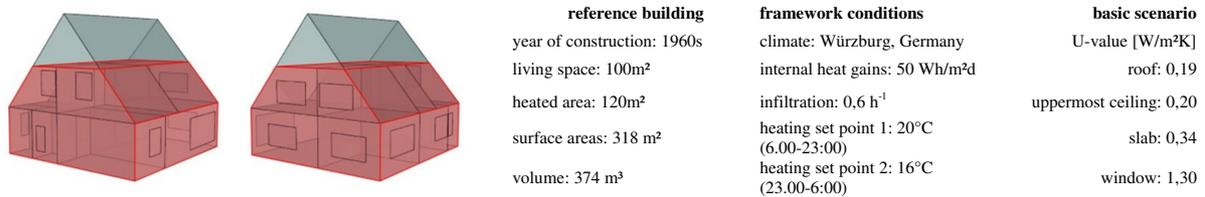


Figure 3: model of reference building and framework conditions for thermal simulation

The assumed basic retrofit scenario consists of 20 cm of mineral wool in the roof, 12 cm of wood fibre insulation boards (WFIB) on the uppermost ceiling and 6 cm of polyurethane (PUR) foam on the slab. With a simulated heating demand of 20,633 kWh provided by a gas condensing boiler, the basic scenario has an environmental impact of 82,449 MJ PEI/a and 4,888 kg GWP/a and estimated operational costs of 1,566 €/a. In order to find out the best retrofit option for the façade, several scenarios were analysed. Four scenarios for heating systems were chosen. Apart from a conventional gas-fired condensing boiler we chose three electric heat pumps (HP) of different annual performance factors (APF): 3.5 for standard HP, 4.8 for efficient products and 7.0 for high-performance systems (e.g. in combination with a thermal store). The environmental data for electricity were taken from the European mix of 2020 (El-KW-Park-EU-25-2020 –PRIMES [9]), including grid losses. We chose six common ways of construction and 19 possible insulation materials as listed in table 1. In order to analyse all possible retrofit solutions, we varied the thickness of the insulation layer from 1 to 70 cm in steps of 2 cm. In combination with the four heating systems there are 15,960 retrofit variants. However, the applicability of the respective insulation material depends on the chosen construction. Furthermore, the total thickness of the construction was restricted to 10 cm for the interior insulation and to 50 cm for exterior measures. To facilitate the review of the results interest rate, discount rate and subsidies were not taken into account in this case study.

By means of a programmed set of loops, all possible solutions were evaluated and written into a spreadsheet. The spreadsheet served as a reference for the optimization process. The

objective for the optimization can be set to one of the key data, such as minimum GWP_{lc} , minimum $Cost_{lc}$ or minimum specific CO₂ abatement cost ($Cost_{inv}/GWP_{lc,saved}$). In the following, the process of optimization is exemplified by the minimization of $Cost_{inv}/GWP_{lc,saved}$. There is a range of optimizers available for *Grasshopper3D*. We employed an evolutionary solver provided by the plug-in *Goat* which uses the *CRS2* algorithm from the *NLopt library* [10]. The minimum of $Cost_{inv}/GWP_{lc,saved}$ was determined as fitness function. Three free parameters – heating system, combination, thickness – are passed on to the optimizer. To integrate constraints of insulation and construction combinations or different construction space limits in the fitness function, penalties were added. The optimum of 127.72 €/t was found in the 408th simulation run. Afterwards the solver continues to search for a better solution but the diversity is slowly reducing. With one thermal simulation of *E+* that took about 7 seconds, the whole process lasted 2.5 hours. In order to find the Pareto front for minimum GWP_{lc} and $Cost_{inv}$ we employed an evolutionary multi-objective algorithm provided by a plug-in called *Octopus*. The Pareto front, as it is displayed in Figure 5, is a selection of variants with an allocation of criteria where it is impossible to improve any criterion without making at least one criterion worse.

Results of life cycle assessment

The rating of all variants, according to GWP_{lc} , indicates that constructions with a high percentage of renewable raw materials (*VF*-wood cladding with insulating layers of hemp fibre) in combination with a low-emission heating system (WP 7.0) perform best down to 365 kg/a. (shown as point A in Figure 5) Due to the very low embodied impact (GWP_e) there is no optimum of GWP_{lc} in the range of 1-50 cm. While the insulation thickness increases, the GWP_{lc} decreases continuously. However, the curve is very flat when using a HP 7.0 causing the reduction of GWP_{lc} to be less than 5% between 28 and 50 cm. The curve for *WFIB* is similar.

The lowest GWP_{lc} for a HP of 4.8 lies at 511 kg/a, for a HP of 3.5 at 694 kg/a and at 1657 kg/a using the gas boiler for heating. All that was achieved by *VF* with 50 cm hemp fibre. With less efficient heating systems the effects of increasing insulation thickness are more significant. Within a 5% range of the best variants using gas heating the following combinations can be found: *VF*-wood cladding with 32 cm HE, with 36 cm *WFIB* or with 50 cm GW. The best variant using *ETICS* with *EPS* shows a GWP_{lc} of 2,017 kg/a with an insulation thickness of 22 cm. The most economical solution is based on $Cost_{LC}$, a 6 cm thick interior insulation in combination with a gas boiler with 1,055 €/a (shown as point B in Figure 5), followed by *ETICS* with 14 cm *EPS* insulation at 1,108 €/a (point C). The following variants range within a 5% divergence from this best solution: *ETICS* with 8-22 cm insulation (1,108-1,133 €/a) and *VF* with wood cladding and 12-24 cm insulation (minimum 1,157 €/a at point D). Increasing the insulation thickness from 12 to 20 cm does neither improve nor worsen the cost efficiency. However, thicknesses of more than 30 cm show an increased $Cost_{lc}$ of more than 10%.

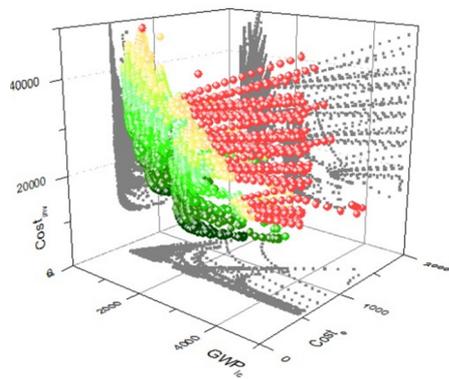


Figure 4: response space of all variants in order to GWP_{IC} , invest, operational cost

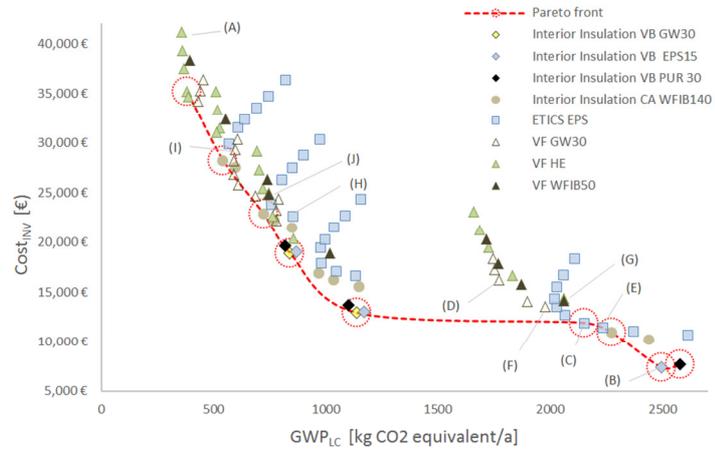


Figure 5: Pareto front and selection of variants according to invest costs compared to GWP_{IC}

The CO₂ abatement costs allow an assessment at the macroeconomic level to adjust funding policy and subsidies. Furthermore, the CO₂ abatement costs are comparable to the target price for emission certificates. The results indicate that the variants with interior insulation (independent of the insulation material) have the lowest CO₂ abatement costs (127 kg/€ to 137 kg/€), well in advance of any other construction. However, it should be pointed out, that interior insulation is subject to heavy restrictions and needs an in-depth analysis of the hygrothermal behaviour of the existing wall to avoid condensation. The problems of thermal bridges (inadequately insulated elements that connect to exterior walls) have not been taken sufficiently into account in *E+*. The restriction of the interior insulation thickness may be a disadvantage if a high energetic quality of building envelope is required. Nonetheless, the analysis shows that these low-investment measures have a high CO₂-saving potential which should increasingly be considered in the promotion of retrofit measures. Since interior insulation is a special case due to the critical points mentioned above, we explored the most cost-efficient solution among the other variants. The two best variants are: *ETICS* with 8 cm *EPS* at 173.5 €/t (point E in Figure 5) and *VF* with 14 cm *GW30* at 186.2 €/t (point F). Using *WFIB* in *VF* raises CO₂ abatement costs up to 200.1 €/t, the optimum being at 12 cm (point G). In those cases the heat is provided by a conventional gas boiler. The lowest CO₂ abatement costs employing a *HP* of 4.8 are 225.1 €/t applying *ETICS* of 4 cm insulation thickness (point H), 235.6 €/t for *VF* with an 8 cm thick *GW30* (point I) and 240.4 €/t for *VF* with a 6 cm thick *WFIB* (point J in Figure 5).

Conclusion

First of all, the results clearly indicate the sizable dependency on individual determining conditions and therefore the necessity of their consideration within the planning process. Secondly, the solution for the best retrofit measure considerably varies, depending on the assessed optimization criterion. Furthermore, the results show that, due to the current price level, renewable insulation material cannot yet compete with conventional material in the question of cost efficiency. On the other hand, the study shows the very limited range of



optimal thicknesses for the application of conventional insulation material. Hence, for high insulation standards requiring greater thicknesses either renewable materials or renewable forms of energy have to be employed. The combination of both shows the highest efficiency in order to achieve a nearly zero-emission buildings standard.

The presented parametric life cycle assessment method in combination with multi-criteria optimization proved to be suitable for the systematic evaluation of a great amount of variants. The optimization process took quite a long time, due to the time-consuming simulation with *E+*. In future, it will be investigated how simpler demand calculation can be used for the first estimation to speed the process up.

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Environmental Impact of Housing Retrofit Activities: Case Study

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Abstract: *During any construction project, a huge number of resources are used and a significant amount of waste is generated. In addition energy is consumed in both construction and operational phases of the project. As a result, the environmental impact of a construction project can be significant. One way to decrease the negative impact of the project on the environment would be to consider building green retrofitting. One of the main features of sustainable building retrofitting is to convert an existing building to a low energy facility. This study attempts to evaluate the environmental impacts of sustainable housing retrofit during the operational phase of a building by calculating and comparing the amount of air emissions (including CO₂, SO₂, and NO_x) of an ordinary house to those of a green retrofitted one. In order to accomplish these tasks, the case study of a house, built in 1960's in Albuquerque, NM, and considered for green retrofitting, is presented. The results show that low cost activity of Lighting, medium cost activity of Insulation, and high cost activity of Renewable Options have the most positive environmental impact during the operation of the building. According to the results, applying retrofitting activities could decrease the environment impact in terms of air emissions of the operating building to more than half.*

Keywords: *Sustainability; Housing Retrofit; Environmental Impact; Green Building.*

Introduction

In recent years, building environmental issues have become increasingly important. The construction and building sector has been found to be responsible for a large part of the environmental impacts on human activities [1] consuming almost 50% of the total energy each year [2, 3]. The construction sector also contributes significantly to the global depletion of natural resources, clean air, and water, representing the largest consumer, by far, of raw materials in the United States during the twentieth century [4]. In addition, it is worthwhile to mention that the majority of the energy consumed by buildings occurs over the duration of their service lives [4, 5], and contributes to anywhere from 52% to 82% of the total life cycle energy consumption of a building [6].

One way to reduce the adverse impacts of buildings on the environment is to focus on sustainable buildings that target energy efficiency. Dong et al. stated that it is more sustainable to utilize existing buildings rather than demolish them [4]. Thus, the construction industry is challenged to reduce the environmental impacts of the built environment through building retrofit.



Sustainable housing retrofit is an effort to convert a house to a low energy facility, to analyze the deconstruction techniques, and to evaluate the alternatives for installing reused/recycled materials. Current building standards ensure that new buildings are highly energy-efficient, however, it would be a greater challenge to upgrade older, less efficient dwellings to higher energy efficiency standards [7]. Thus, efforts to improve the energy consumption performance of existing buildings are much more difficult to achieve than in new construction [4].

While there is considerable information about operational phase energy reduction strategies for retrofitting housing stocks, there is far less knowledge on the Life Cycle Impact Analysis attributable to retrofitting [7]. This study attempts to evaluate the environmental impacts of sustainable housing retrofit considering energy consumption. In other words, the following study tries to calculate and compare the amount of air emissions (including CO₂, SO₂, and NO_x) of an ordinary house to those of a green retrofitted one. In order to accomplish these tasks, the case study of a house, built in 1960's in Albuquerque, NM, and currently being considered for green retrofitting, is presented. The intent of this study is to simulate the steps that would be taken by an average homeowner when retrofitting this house and to analyze how effective these measures are to obtain the most efficient sustainable level.

Green Building Retrofit

In order to conserve the non-renewable resources, a green building consumes minimum natural resources during its construction and operational phases. It also emphasizes the reuse, recycling and utilization of renewable resources. A green building focuses on increasing the efficiency of the use of the resources [3]. There are many benefits of green buildings such as: reduced energy consumption, reduced damage to nature, reduced water consumption, limited waste generation due to recycling and reuse, reduced pollution loads, and enhanced image and marketability.

Sustainable retrofit is a capital improvement with an associated cost that resets the building life, improves performance, and makes the building's use more predictable for an extended period of time [5]. The decision to retrofit existing buildings still presents a number of challenges to the building stakeholders due to: [1] lack of information and benchmarks about the actual performance of the building and its systems after the design phase, [2] reluctant stakeholder commitment because energy prices and [3] taxes are not high enough to create a strong incentive for retrofits [8], and [4] perceptions from early green buildings that significantly higher costs outweigh economic and environmental benefits [5]. The main obstacles to sustainable retrofits are high construction costs, long pay back periods, and difficulty in quantifying the benefits of green building.

The evaluation of green building is a complex issue which requires a life-cycle perspective [9]. The system boundary of a house retrofit project should be limited to only those processes that cannot be separated from the building [7].

Case Study

The University of New Mexico is working with the Associated General Contractors of New Mexico and the Central New Mexico Home Builders Association to remodel an existing home as a demonstration project. One of the goals of the projects is to gather data and demonstrate the effectiveness of various remodeling techniques. As a collaboration of industry leaders in research, construction, and residential building; it is envisioned that this partnership will develop a synergy for future benefits to the community.

The house being studied was originally constructed in 1964 as a ranch home in Albuquerque, New Mexico. In 1986, the facility was donated by the Associated General Contractors of New Mexico (AGC-NM) to the University of New Mexico as part of an endowment package for the Construction Management Program in the Civil Engineering Department. Since that time, numerous visiting professors and occasionally new hired professors have lived in the home. Most of the minor repairs on the home have been conducted using funds from the endowment and from volunteer work from the faculty and students. Essentially, all of the repairs on the home were intended only to keep the facility habitable and no major energy conserving features have been added.

The home is a 1500 square foot 3 bedroom 2 bath concrete block facility constructed on a crawlspace (Figure 1). There is a relatively flat gable roof with a 1:12 pitch. The ridge of the roof runs through the middle of the building in a north south direction. Roofing construction is a ballasted built up roof system using bituminous material. The current heating is by gas furnace and cooling is provided by an evaporative cooling (swamp cooler) system. The building site is a 0.28 acre lot that has a grass lawn and several planted landscaped areas. There is a covered carport and an external storage shed.

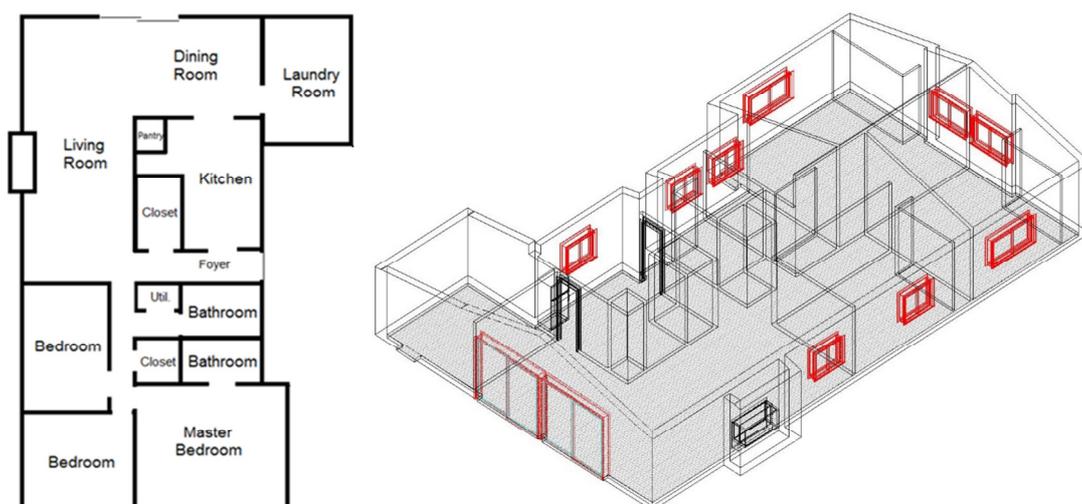


Figure 1. House layout

The building has been occupied by a family of three for the last two years. During that time, the annual utility usage has been 9,000 kWh of electricity, and 700 therms of gas. The average Albuquerque, New Mexico utility usage provided by PNM, the local utility company,

for a similar size and age of home is: 9307 kWh per year and 755 therms of natural gas [10]. Therefore the actual usage of utilities for the home is directly in line with the average Albuquerque utility usage for a similar constructed and age of facility.

Retrofitting Plan

The “Build Green New Mexico criteria for a Green Building” document is used to evaluate the steps that could be taken to retrofit the house. In determining the priority of retrofitting activities, the process starts with the basic least expensive items from the building and works up towards more complex items to finish with on-site renewable energy systems. Figure 2 provides a summary of the planned activities for retrofitting of the house.

Controlling	<ul style="list-style-type: none"> • Programmable Thermostat • HVAC tune up
Lighting	<ul style="list-style-type: none"> • Replace all lighting with CFLs
Appliances	<ul style="list-style-type: none"> • Replace with Energy Star for Refrigerator • Replace with Energy Star for Clothes washer • Replace with Energy Star for Dishwasher
Insulation	<ul style="list-style-type: none"> • Insulate Ceilings • Insulate walls • Insulate Attic
Windows & Doors	<ul style="list-style-type: none"> • Replace doors with insulated core • Replace windows with energy efficient glass
Heating & Cooling	<ul style="list-style-type: none"> • Install ground source heat exchanger • Evaporative Cooler
Renewable Options	<ul style="list-style-type: none"> • Solar Thermal • Solar electric

Figure 2. Planned renovation activities

Energy Simulation

In this research, the house case is modeled by eQuest v3.65. eQuest is a user friendly software that: provides an interface to create a detailed building model; allows to automatically perform parametric simulations of the design alternatives; and provides graphics that compare the performance of the alternatives. eQuest calculates hour-by-hour building energy consumption over an entire year using hourly weather data for the location under consideration. Input to the program consists of a detailed description of the building being analyzed, including hourly scheduling of occupants, lighting, equipment, and thermostat settings.

For simulating the case study, the house is first modeled as it is, without considering any retrofitting activities. Figure 3 shows the output of the case house modeling in terms of electricity and natural gas consumption of the building.

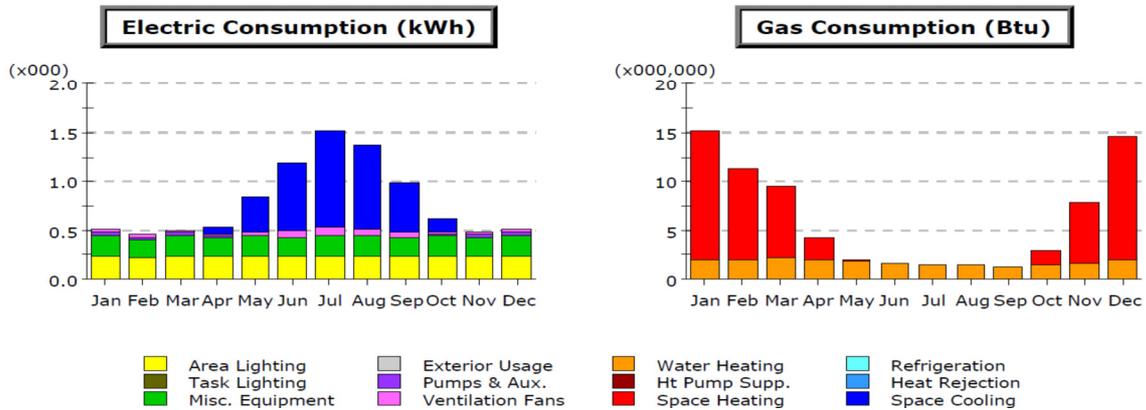


Figure 3. Energy consumption of the house as it is

As the results show, the annual electric and gas consumption of the case house are 9,550 KWh and 73.42 MBtu, respectively. Therefore the simulated energy consumption for the home is in line with the average actual usage of utilities (9,000 kWh of electricity, and 70.0 MBtu of gas, respectively).

Figure 4 provides a comparison between the percentage of average US home energy consumption type with the percentage of annual energy consumption types for the case house.

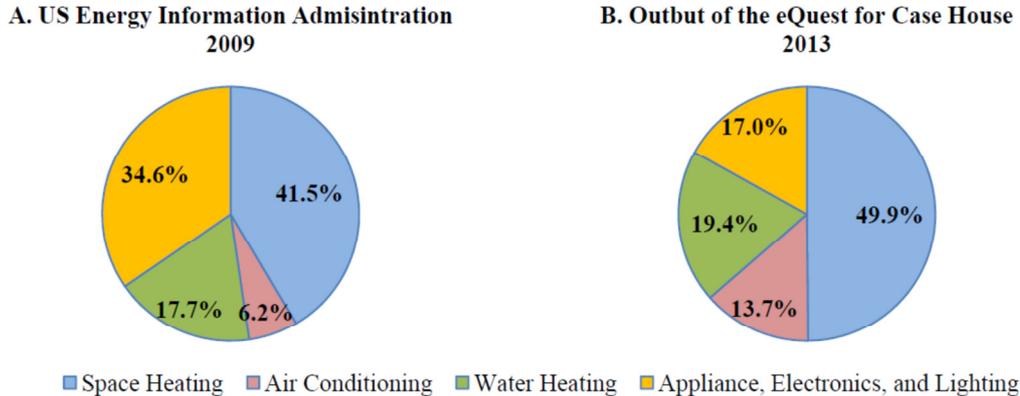


Figure 4. Comparison of energy consumption by end users

The second step of the simulation, considers the implementation of each retrofitting activity into the model and the impact of these activities on the annual energy consumption of the house.

Energy Emissions Factors

In the United States, electricity is generated in many different ways, with a wide variation in environmental impacts. Electricity generation from the combustion of fossil fuels contributes towards air pollution, acid rain, and global climate change [11]. According to EPA, power emissions factors are determined based on the power grid region; and the air emissions rates of the electricity in the region are compared with that of the national average. As the Natural Gas website states [12], burning natural gas in place of other fossil fuels emits fewer harmful

pollutants, and an increased reliance on natural gas can potentially reduce the emission of many of these most harmful pollutants. Table 1 summarizes the energy emissions due to electricity and natural gas use.

Table 1: Energy emissions factors

Energy	Reference	Air Emissions		
		NO _x	SO ₂	CO ₂
Electricity	[11]	1.52 lbs/MWh	0.62 lbs/MWh	1,191 lbs/MWh
Natural Gas	[12]	0.092 lbs/MBtu	0.001 lbs/MBtu	117 lbs/MBtu

Results and Discussion

According to the estimated amount of electricity and natural gas consumption of the case study building, the amount of emissions that would be released during the operation of the building are: 21.3 lbs of NO_x, 6.0 lbs of SO₂, and 19,962 lbs of CO₂ per year. Also the amount of CO₂ emission during the operation is equal to 13.3 lbs/ft².year (64.9 kg/m².year), that can be compared to other research results from 13.9 kg/m².year in Spain [13] to 260 kg/m².year in China [14].

Considering the energy savings associated with each activity as well as energy emissions, the amount of air emission reductions resulting from implementation of each retrofitting activity is calculated. Figure 5 summarizes air emission reduction results.

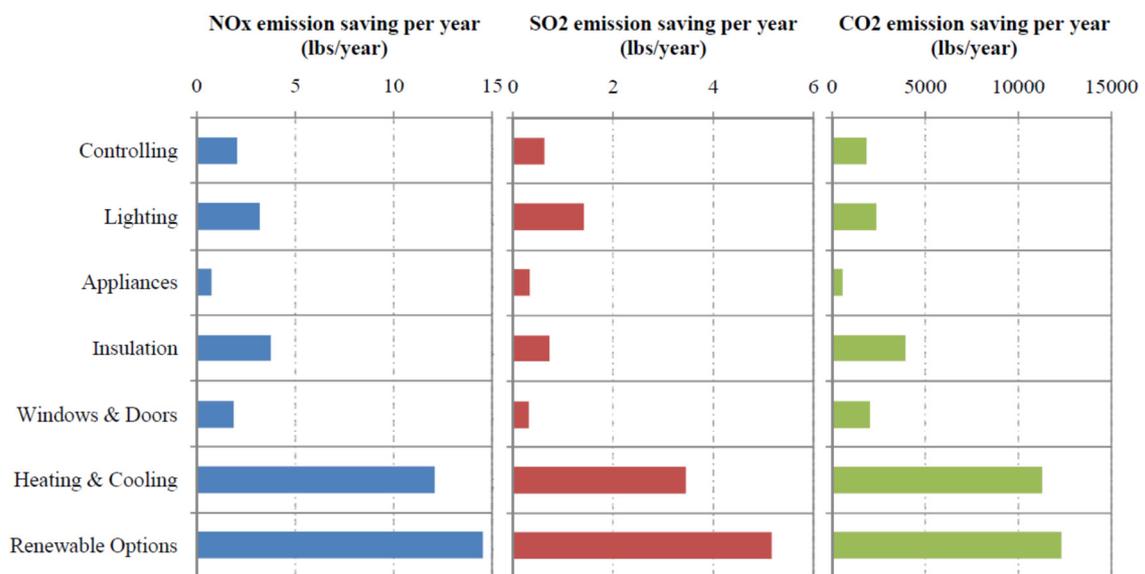


Figure 5. Environmental impact of retrofitting activities

As the figure shows, from the low cost retrofitting activities, lighting is the most significant system that can cause a considerable amount of emission reduction in comparison to other low cost retrofitting activities. After that, insulation is a medium cost retrofitting activity that can cause a high reduction of NO_x and CO₂ emissions. However the two last activities, heating & cooling and renewable options, which are categorized as high cost retrofitting activities have



the most positive environmental impact. According to the results, applying these activities could decrease the environment impact in terms of emissions of the operating building to more than half. Therefore, the low cost activity of Lighting, medium cost activity of Insulation, and high cost activity of Renewable Options have the most positive environmental impact during the operation of the building. It is important to mention that the results show the positive environmental impact of each activity separately. In other words, implementing more than one activity does not imply that the resulting emissions can be summed up.

Conclusion

This study attempted to evaluate the environmental impacts of sustainable housing retrofit considering energy consumption. The study tried to calculate and compare the amount of air emissions (including CO₂, SO₂, and NO_x) of an ordinary house to those of a green retrofitted one, using a case study of a house, built in 1960's in Albuquerque, NM.

The results of simulation showed that the amount of emissions that would be released during the operation of the building are: 21.3 lbs of NO_x, 6.0 lbs of SO₂, and 19,962 lbs of CO₂ per year. However applying retrofitting activities could decrease the environment impact in terms of air emissions of the operating building to more than half. The results also illustrated that low cost activity of Lighting, medium cost activity of Insulation, and high cost activity of Renewable Options have the most positive environmental impact during the operation of the building.

This research introduces an approach to determine the environmental impacts and air emissions of a retrofitted house, according to savings in energy consumption. The intent of this study is to simulate the steps that would be taken by an average homeowner when retrofitting a house and to analyze how effective these measures are to obtain the most efficient sustainable level. Therefore, the results of this study may have some limitations such as neglecting the environmental impact of water consumption and the amount of waste generated when retrofitting the house. A complete life cycle assessment of the sustainable housing retrofit is needed in future researches.

Acknowledgements

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Relevance of the recycling potential (module D) in building LCA: A case study on the retrofitting of a house in Seraing (Best Paper SB13 Graz)

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Abstract: *Following the European standard concerning the sustainability of construction works EN 15978, the informative module D allows crediting a building for the recycling potential of its materials and the exported energy. Whereas the relevance of this module has largely been associated with the environmental assessment of metals so far, it is not clear to what extent module D is relevant in the life cycle assessment (LCA) of buildings. In this paper a building renovation case study is considered to investigate and discuss the implications of including module D in a building LCA.*

The environmental impacts of the building elements and materials are analysed using a cradle-to-grave LCA, including module D. The impacts related to the different life cycle stages are compared to each other and discussed in relation to the input and output materials. The results initiate a discussion on the controversial module D and illustrate the potential effects of this module compared to the rest of the life cycle.

Life Cycle Analysis (LCA), Recycling, Module D, Renovation, Environmental Assessment, Building LCA, LCA Methodology, System Boundary

1 Introduction

The consideration of recycling aspects in life cycle assessment (LCA) has been a point of discussion for several years. In general there are two contrasting approaches to account for recycling in LCA: (1) the recycled content approach, which considers the benefits of recycling at the input side of the life cycle and (2) the end of life recycling approach, which accounts for the benefits of recycling at the output side of the life cycle [2].

According to the European standards concerning the sustainability of construction works EN15804 [3] and EN15978 [1], a building's life cycle information is organized along three major life cycle stages: (A) the product and construction process stage, (B) the use stage and (C) the end of life stage. The system boundary at the end of the life cycle is set where outputs have reached the "end-of-waste" state, leading to the recycled content approach. However, for the building assessment information, the standard identifies an additional optional life cycle stage (D) describing the benefits and loads beyond the building life cycle. This stage, also called module D, allows crediting a building for the recycling potential of its materials or the exported energy. The calculation of module D thus allows using the end-of-life recycling approach.

The consideration of module D is argued to be important for metals [2], but it is not clear to what extent this approach impacts the results for building LCA's. In this paper a building renovation case study is considered to investigate and discuss the implications of including module D in an LCA for buildings.

2 Case study

The renovation of a 4-storey high multi-family house located in Seraing (Belgium) is analysed for this study. This building, containing 3 apartments and a commercial space, has been deeply renovated in order to meet the current needs and standards in terms of comfort, space and energy requirements.

The existing building was composed of brick and a sloped roof with ceramic tiles (see Fig. 1). The main structure of walls and floors are preserved during the renovation. The external walls are insulated from the inside, using a system wall with a metal structure. The original street façades are preserved and the façades of the new top floor and south side are covered with metal sheeting. All windows and doors are replaced and new interior walls are assembled using a dry wall system. The entire roof structure is removed and replaced with a steel structure and steel roof covering in order to provide a useable living space on the third floor (see Fig. 1).



Fig. 1: Case study: Multi-family house in Seraing. Representation of the old situation (left) and the renovated situation (middle and right)

3 Methodological approach

LCA is a technique to assess the environmental impact of a product throughout its life cycle, from raw material extraction, via production and use phases to waste management. This study is performed according to the principles of ISO 14040 [4,5], which defines the methodological framework for LCA, and the harmonised European standards EN 15804 [3] and EN 15978 [1], which describe the methodology and calculation methods for the environmental assessment of building materials and buildings. More details on the considered approach (system boundaries, LCI and LCIA) are available in the extended version of this paper [16].

3.1 Goal and system boundaries

The aim of this study is to evaluate the environmental impact related to specific retrofitting actions performed during the renovation of a building in Seraing and to discuss the potential effects of module D compared to the rest of the life cycle. The functional unit is a 4-storey high multi-family house with three living units and a commercial space, a total floor area of 280 m² and a reference service life of 60 years.

The LCA is a ‘cradle-to-grave LCA including module D’, with consideration of the stages listed in Table 1. For materials going to recycling, the system boundary between the system under study and the system that will use the waste is set at the gate of the sorting plant.

Table 1: Overview of life cycle stages considered in the LCA, according to EN15978 [1]

Product stage	A1-3	Production of new materials
Construction process stage	A4	Transport of new materials
	A5	Installation of new materials
Use stage	B4	Replacements: Disposal of materials that need to be replaced and production, transport and installation of the new materials
	B6	Operational energy use of building-integrated technical systems, which are covered by the Energy Performance of Buildings Directive
End of Life stage (EOL)	C1-4	Demolition process, transport to the treatment facility, impact of EOL treatment and final disposal
Benefits and loads beyond the system boundary	D	Reuse-, Recovery-, Recycling- potential

Following EN 15978 [1], the informative module D declares the potential loads and benefits of secondary material, secondary fuel or recovered energy leaving the product system. This module is primarily intended to describe in a transparent way the potential benefits of avoided future use of primary materials and fuels – and loads associated with the recycling and recovery processes.

In this study, module D reports on the loads and benefits of:

- the recycling potential of materials
- exported energy generated by photovoltaic panels.

Materials for energy recovery (e.g. through incinerations) are not considered because of the lack of data available on the efficiency of waste incineration installations in Belgium. As a result, the impact of materials being incinerated is fully allocated to the building life cycle).

3.2 Life cycle inventory (LCI)

The LCA is modelled using Simapro software. Generic data is used from the ecoinvent database v.2.2 [6], harmonized with the Belgian/European energy mix. The study makes use of the transport and EOL scenarios established within the Flemish study OVAM MMG [7], which describe the typical transport distances, routes and transportation modes for different product material groups.

The recycling scenarios considered for this study are based on current average technology or practice (see Table 2). For materials recycled in a closed loop (such as steel), any secondary materials used as inputs for the system are subtracted from the secondary material leaving the system at the end of life, in order to avoid double counting and calculate the net impacts for the net output flow. Recycled content is based on average current production technologies.

Table 2: Scenarios used to determine the recycling potential at the end-of-waste point (to be declared in informative module D)

Material to be recycled	Secondary material
Steel	Secondary steel (closed loop)
Concrete, screed, ...	Secondary granulates for roadwork (open loop)
Concrete blocks, bricks, facing tiles, ...	Secondary granulates for roadwork (open loop)
Untreated sawn timber, wooden boards (MDF, OSB), parquet ...	Wood chips (open loop)
Interior plaster (crushed together with concrete granulates)	Secondary granulated for roadwork (open loop)
Facing tiles, ceramic wall and floor tiles, ...	Secondary granulated for roadwork (open loop)
PE-foil, vapour barrier, ...	Secondary PE granulates (open loop)
Gypsum plaster board	Gypsum plaster (open loop)
Aluminium in window frames	Secondary aluminium (closed loop)
Glass	Glass cullets (closed loop)

Technical installations for heating and ventilation, sanitary installations and electrical installations are excluded from the study. The life cycle of the building renovation is set to 60 years for the analysis. Building elements with a shorter life span are considered to be replaced



during this period. Assumptions regarding the probable service life of the materials and components are based on standard values used in the ecoinvent database v2.2 [6] and existing LCA tools, as well as values from literature [e.g. 8,9].

3.3 Life cycle impact assessment (LCIA)

After an analysis of different impact assessment methodologies [10,11], we opted to interpret the LCI results using the ReCiPe method [12]. This method makes use of the state of the art LCIA methodologies and it enables to present the results both at midpoint and endpoint level. Even though the ISO and EN standards do not recommend the weighting and aggregating of different impact categories it allows for an easier comparison and interpretation of the results.

4 Results

First, we discuss the environmental impact of the total building over its considered life cycle stages. Then, the results are broken down according to the different building elements.

4.1 Total impact per life cycle stage

The impact related to the energy use over the building’s considered service life (60 years) clearly dominates and represents about 80% of the building’s total life cycle impact (Fig. 2). Within this energy use, the largest impact is related to the use of energy for heating. The energy gains from energy generated by the photovoltaic cells are reported in module D, but seem to be insignificant.

The impact of the materials introduced for the retrofitting works is organised according to the different life cycle stages: production, transport, construction, replacement, end of life, and recycling potential (Fig. 2). The largest material impacts result from the production stage. Next, the impacts resulting from module D and the replacements are in the same order of magnitude. Finally, the impacts related to transport, construction and end of life are negligible compared to the other life cycle stages.

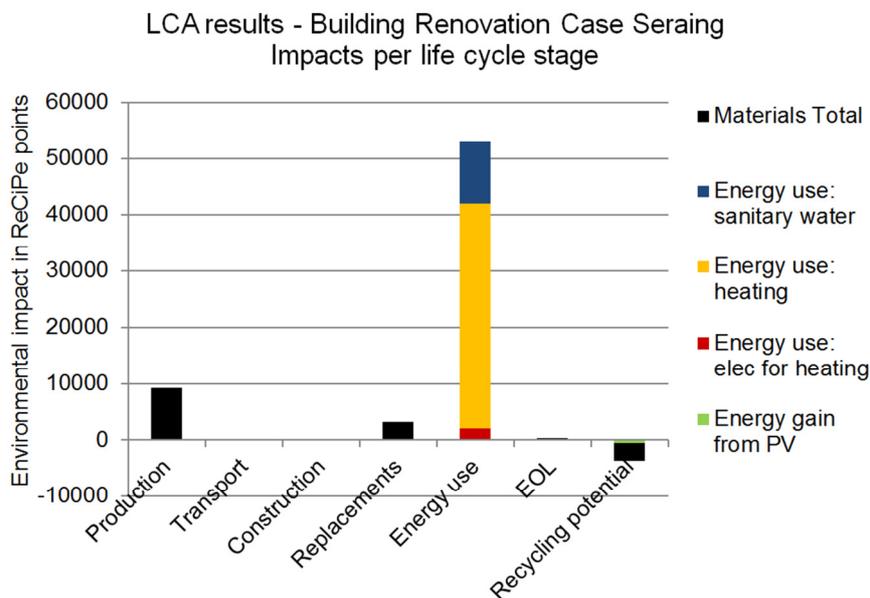


Fig. 2: Impacts of the total building renovation case per life cycle stage, including module D.

4.2 Production, installation and EOL of materials

When excluding the impacts of the energy use during the use phase, the results can be evaluated per building element (Fig. 3). The highest environmental impact among the different building elements is related to the materials for the roof and intermediate floors. Also the exterior walls, interior walls and windows and doors have a considerable impact. A detailed description of the materials leading to these environmental impacts is available in [16].

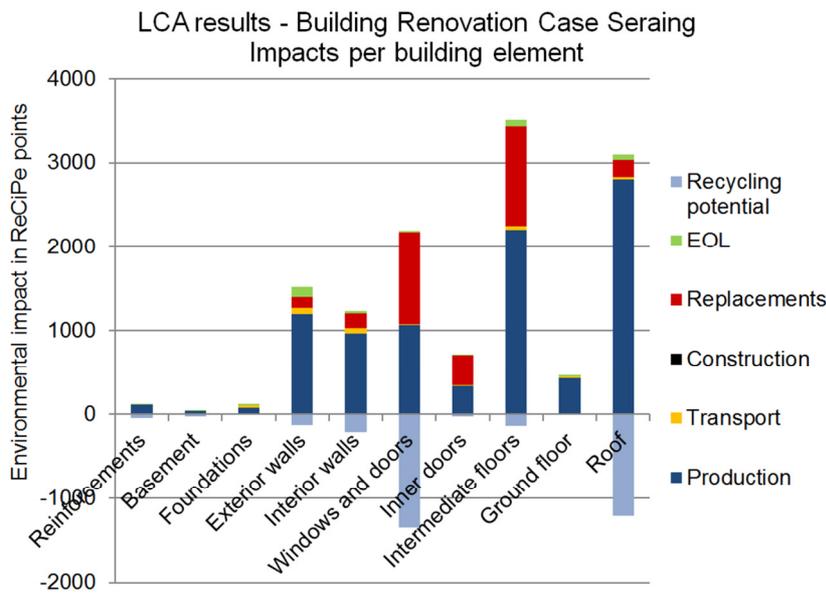


Fig. 3: Environmental impact of the materials over their life cycle, according to the different building elements, with indication of recycling potential (module D).

4.3 Replacements of materials

Fig. 3 shows that the impact of the replacements is significant for the windows and doors, which are replaced once during the considered life cycle. Also the replacements of the wooden floors after 30 years have a substantial impact. Most of the materials used for the building envelope (exterior walls and roof) do not have to be replaced during the reference service life. Consequently, the initial impact of the materials dominates the material impact for most building elements. However, we should note that the study does not account for repairs or partial replacements during the life time, which implies that the calculated impact is slightly underestimated.

4.4 Module D

The environmental impacts related to the recycling potential (module D) are represented in Fig. 3 as negative impacts and can be compared to the impacts related to the other life cycles. This shows that the potential benefits from recycling the materials are considerably high for both the roof and the windows and doors. For the roof, 98% of the avoided impacts are related to the high use of steel, where 95% up to 99% is recycled into new steel (see Fig. 4a for

network diagram). Also for the windows, the majority of the avoided impacts can be linked to the high recyclability of aluminium (98% of module D impacts). The high recyclability of the glass panes (with 70% recycling rate) represents only a small part of the module D impact (see Fig. 4b for network diagram).

The impacts reported in module D for the other building elements are rather small (Fig. 3) because of the non or low recyclability of the materials (e.g. mineral wool, gypsum board), or because of the low benefits related to the recycling process (e.g. concrete, bricks). For the exterior and interior walls, the potential benefits in module D can be linked to the use of steel for structural purposes (supporting beams and metal frame for dry wall system). In the intermediate floorings, the module D impact is related to the recyclability of the hard wood floors into wood chips.

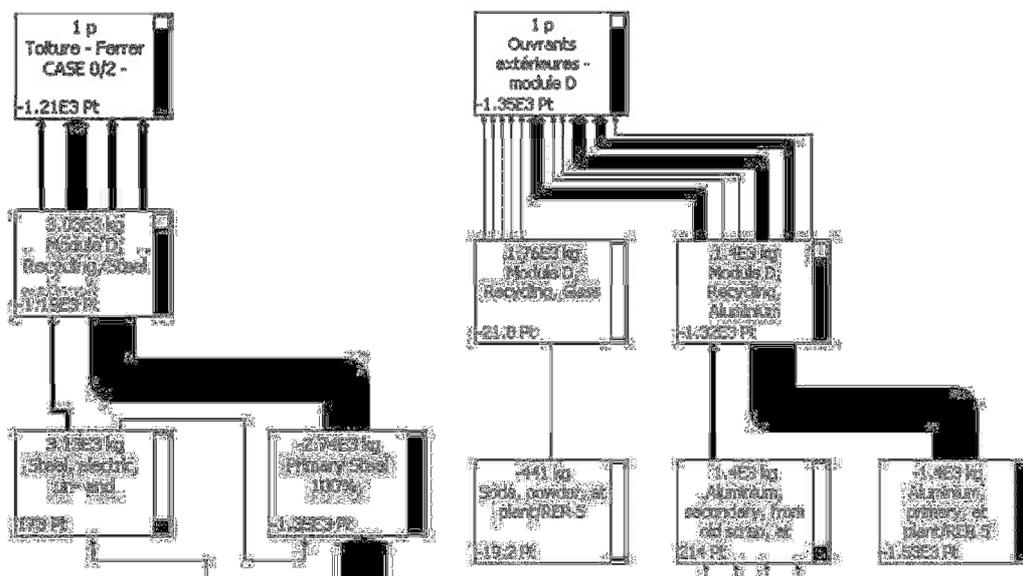


Fig. 4: Network diagram illustrating the materials representing the major impacts in module D for (a) the roof and (b) the windows and doors.

5 Discussion

5.1 Dominance of use phase

Comparing the environmental impacts generated over the different life cycle stages, the LCA results reveal that the highest environmental impacts are related to the energy use during the occupancy phase of the building. This is in line with several other building LCA studies, which illustrate that the building occupation phase is the most important stage in terms of environmental impacts - especially for conventional buildings - and that these impacts can mainly be related to the heating demand [e.g.13-15]. The results of this study confirm that the initiatives to perform better from an environmental point of view, should first be considered from the point of view of reduction of energy during the use phase. Alternative energy production systems, as well as higher insulation levels might lead to a decrease of the building's overall environmental impact.



However, it should be noted that the relatively high importance of the use phase compared to the impact of the materials is also largely related to the fact that it concerns a renovation project: besides the limitations in terms of thermal performance (e.g. thermal bridges, air tightness), only a limited amount of new materials are being added to the renovated building. Consequently, relatively seen, the impact of the energy during the use phase is likely to be higher for a renovation project than for a new construction.

5.2 Relevance of module D

The results of this case study analysis suggest that the consideration of module D at building level can be significant: the module D impacts are of the same order of magnitude as the impacts of the replacements, and are significantly larger than the impacts related to the transport, construction and EOL of the materials. This suggests that, even though module D is stated to be optional, it can provide some relevant additional information concerning the recycling of materials at the end of life.

However, it should be noted that the case considered for this study contains a lot of metals. Whereas the large amount of recyclable materials was partially the incentive for calculating module D in this LCA study, the results also reveal that the potential benefits reported in module D are strongly - or even almost strictly - related to the use of metals. This confirms the relevance of considering module D for metals [1] but makes it hard to discuss the relevance for other building materials.

It is surprising that certain materials with high recycling rates (like glass or concrete) are hardly visible in module D. Typical Belgian buildings usually use large amounts bricks and concrete materials with high recycling rates (around 95%). In the present case only a small amount of these materials is considered for the LCA as the majority of walls is preserved during the renovation. Nevertheless, the small module D impacts can also be explained by the fact that bricks and concrete are considered to be down cycled into secondary granulates to be used for roadwork (common practice in Belgium). Their avoided impacts thus relate to the mining and crushing of primary granulates, which is far less energy and resource consuming than the production process of the concrete or bricks themselves and therefore will not outweigh the impact related to the production phase. Thus materials with high recycling rates do not necessarily relate to high (avoided) impacts in module D.

In general, one should be conscious of the fact that the impacts reported in module D do not tell the complete story about a material's potential beyond the system boundary. Whereas the module D impact might be relatively small for materials like concrete or bricks, it reveals nothing about issues like avoidance (or production) of waste or market demand for recycled materials.

6 Conclusions

Comparing the environmental impacts generated over the different life cycle stages, the LCA results reveal that the highest environmental impacts are related to the energy use during the occupancy phase of the building. However, for buildings with a better thermal performance



(such as passive houses or nearly zero energy buildings) and for new constructions (with a larger amount of materials used for the building), the relative importance of the use phase will become smaller and the decisions taken at material level will become more significant.

The present study reveals that the consideration of module D in a building LCA is possible and can be relevant. It provides additional information on the potential of materials beyond the building's life cycle and can represent a significant part of the total building impact. For the presented case, the impacts related to module D are larger than those related to transportation, construction and end of life. However, the case also shows that the impacts being reported in module D are strongly related to the use of metals in the building. Based on this study, we can state that module D will show a considerable impact for buildings containing a large amount of metals, but these results cannot be generalized to other buildings without further investigation. Research on the recycling impacts of different types of materials is desirable to get a more holistic view on the value of module D at building scale.

7 Acknowledgements

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Session 107:

Are we advancing towards a truly complete urban regeneration?

Chairperson:

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The role of rehabilitation of buildings in the urban integration, social cohesion and environmental responsibility.

***Abstract:** In the framework of the National Research Plan 2008-2011, our research poses a strategy for the design and evaluation of plans and programmes of urban integrated regeneration. The objective is to develop a study on the role of rehabilitation of buildings in concepts like urban integration, social cohesion and environmental responsibility.*

The research proposes a methodological tool for evaluating urban regeneration processes from a holistic perspective that can serve as a guide for governments and technical teams to address intervention in consolidated urban areas with physical and socio-economic problems.

The development of the tool has inevitably led to delve into different areas where you can intervene but has not lost sight of the complex interplay of factors involved in the process. It is an open source tool to visualize Urban Integrated Rehabilitation processes.

Urban Integrated Regeneration, Urban Sustainability, Social Cohesion, Deprived neighbourhoods.

Urban Integrated Regeneration at European and Spanish framework

The main objective of this paper is to introduce the methodology for integrated urban intervention in neighborhoods developed by GIAU +S (Grupo de Investigación en Arquitectura, Urbanismo y Sostenibilidad de la Universidad Politécnica de Madrid). The role of cities in employment growth in Europe is well recognized; however, many urban areas have high rates of poverty, unemployment and social exclusion and poor quality housing, energy-inefficiency, and environmental degradation.

Our interest is to highlight the role of Integrated Urban Regeneration as a fundamental instrument of intervention in the consolidated city in order to achieve the goals on integrated urban development which have been raised by the European Union in the framework of Cohesion policy for the coming years. Integrated Urban Regeneration seeks to articulate the different areas of the city promoting quality of life, retrieving the “right to the city” of the most deprived areas, and encouraging the process of social and economic inclusion.

Therefore, at European level, the Commission proposes specific investment priorities for urban areas, which concentrate funding for cities in a number of key strategic priorities, but always from an integrated approach. One of these strategic priorities is the economic and physical regeneration of deprived urban areas.

In the Spanish context, distribution of legislative competences and management among the three levels of government (central state, autonomous regions and municipalities) is reflected in the way in which EU policies are implemented. At the central level, urban development - traditionally linked to Housing policies - depends right now on the Ministry of Public Works (Ministerio de Fomento), which sets the reference lines for urban development policy. It also



represents the National Focal Point of the EUKN Network in Spain. On the other hand, the Ministry of Environment (Ministerio de Agricultura, Alimentación y Medio Ambiente) promotes sustainability, among others, at the urban level. Thirdly, the Ministry of Finance (Ministerio de Hacienda y Administraciones Públicas) assumes the role of facilitator between the different administrative levels in Spain, it also channels EU funds, especially the ERDF dedicated to integrated urban development initiatives (URBAN and Iniciativa URBANA).

According to the Spanish Constitution, the Autonomous Community is the administrative level with competences for framing and managing territorial development policies in its territories. However, very few regions have developed tools or specific legislative frameworks to promote urban revitalization from an integrated perspective. The “Leyde Barrios” in Catalonia (2004) and Balearic Islands (2009) have been one notable exception at the regional level, introducing new management tools and funding and integrated vision for urban development. Similarly, IZARTU program promoted by the Basque Government is a territorial cohesion regional initiative, which has supported since 2001 urban projects and integrated local development in a similar approach in the line of URBAN projects.

At state administrative level, urban regeneration and sustainable urban development in Spain is currently framed in a series of laws and national plans: Spanish Strategy for Climate and Clean Energy 2007-2012-2020 Strategy; Law 8/2013 of 26 June, rehabilitation, regeneration and urban renewal; State Plan 2013-2016 to promote rental housing, rehabilitation, regeneration and urban renewal; National Action Plan for Energy Efficiency 2014-2020.

However, so far, the actions have focused on improving neighborhoods from a sectorial perspective, primarily for the maintenance and preservation of housing. In order to address the problems at the scale of the neighborhood, new financial aid has been regulated specifically targeting these areas through the so-called "Integrated Rehabilitation Areas" (ARI) and "Urban Renewal Areas" (ARU) instruments. Although these proposals, focusing primarily on deprived neighborhoods, intend to take account of social, economic and environmental problems of neighborhoods, actions will mainly focus on the refurbishment of buildings, infrastructure works or physical accessibility improvements and new housing within the area. In this sense, these actions don't really represent integrated urban development in the line of URBAN projects or European priorities.

The need for new tools for a comprehensive approach.

From this perspective, it seems necessary to discuss on the need for tools that allow us to visualize the degree of comprehensiveness of the proposals of intervention at neighborhood scale. In this line, our research group (GIAU+S /UPM) is currently working in a project called: “A strategy for designing and assessing plans and programs of Integrated Urban Regeneration Intervention in Spanish peripheral urban areas through Integrated Rehabilitation Areas and URBAN program.”



Intervention in the consolidated city is an instrument in process of revision which requires the implementation of rehabilitation plans and programs that cope with the complexity of urban problems and the diversity of stakeholders. This method of viewing the comprehensiveness of the Integrated Urban Regeneration project is introduced as a response to this challenge.

In order to make this easier, this project aims to define a strategy, in the form of a guiding tool, that facilitates the design and assessment of plans and programs of Integrated Urban Regeneration, taking into account the needs and priority of any intervention in all their aspects (urban environment, urban planning, housing and socio-economics), and all the involved stakeholders.

This methodology is an open source tool that aims to facilitate decision making to visualize relationships between the different fields of action and show the priorities of the proposal. Therefore, it can serve as a basic tool for citizen participation in the processes of Urban Integrated Rehabilitation.

This strategy, established from an urban planning point of view, is based on a legal analysis, considering all the related literature, the opinion of an Expert Panel and the study of existing experiences categorized in a Matrix in which all the items to be addressed by rehabilitation programs are arranged hierarchically.

The guiding tool: an open source matrix.

The proposed method avoids the models that seek to determine the valuation of the results through the allocation values to the different solutions and classify them according to them. Instead, complete visualization of the designed processes ensures that the agents involved in the process (political leaders, technicians and citizens) have to determine what actions are developed and which is relevant to delay or defer time based on priorities and available resources. Thus, the limitations and shortcomings of the proposal are not hidden but are displayed in order to assess the extent of the initial objectives. These objectives should seek better urban quality.

The guide tool comprises a matrix of items grouped in categories which in turn are clustered in four different areas. One of the additional objectives of this work is to analyze the relationships between the areas, categories and items.

The matrix is organized around the four major areas of intervention that all comprehensive approach must include: Regional and Urban Planning, Urban design and local environment, Building and Socioeconomic area.

[OUT]_Regional and Urban Planning Area:



Since, according to the reference document of the Charter of Toledo, Integrated Urban Regeneration is a planned process to be addressed by the city as a whole and its parts function as components of the urban organism. Measures of social and economic intervention or measures physical- environmental intervention located in the neighbourhood are not enough by themselves in isolation but must be linked into overall planning. In this perspective, the localized urban regeneration initiatives should be managed on a global planning framework guided by the basic criteria of the Urban Integrated Regeneration. That is, the planning should be directed to the discrete and comprehensive rehabilitation of the city, with special emphasis on the most deprived areas and the double dimension of planning processes: “political regeneration” (citizen participation in the decision-making) and “physical regeneration”. However, because of the overall design of the research project, this area refers only to the determination of spatial planning of urban or regional planning.

[DMA]_Urban design and local environment Area:

This area includes all aspects related to the physical environment and affecting the neighbourhood for intervention. It considers both the built environment and the natural environment. It also considers the relationship of neighbourhood with those aspects of the immediate environment they can influence the comfort and welfare of all stakeholders (residents, visitors, businesses, etc.).

The main objective is to improve the quality of life and comfort of citizens through regeneration of outer space, both the immediate environment to housing as the rest of the public open space in the neighborhood or area of intervention.

[ED]_Building Area:

The building area is concerned with the analysis, diagnosis and proposals for action aimed at the qualification of living space built. The built environment includes, for all uses present in the area, both proprietary and collective spaces within the building, as the clearances legally bound to it. The intervention will focus on the built support, understood as the collective part of the building managed by (private or public) owners' communities and intended to be permanent. In proprietary spaces, the intervention could only be produced in cases of severe unsanitary conditions, uninhabitability and accessibility deficiencies.

The objective is to determine the actions required to achieve at least the same benefits as the equivalent reference building. New building construction that is homologous to rehabilitate is considered equivalent reference building. For residential use, and in the absence of specific regulations for rehabilitation, the landmark building is the new construction of subsidized housing (VPO).



[SE]_ Socioeconomic Area:

Socioeconomic area deals with the necessary steps towards the achievement of social and economic model that seeks fairness and equal opportunity, including projects for local economic development, social inclusion and associative network support to enable their participation in decision-making.

It aims to explain a proposal for socioeconomic development in the area of action, based on the strengths and opportunities offered by both the physical environment and the social and economic fabric. It seeks to improve the integration of the area of action within the economic dynamics of the city or metropolitan area. The objective is to ensure convergence key indicators on vulnerability and social exclusion (unemployment, income, school failure, delinquency) with the mean values of the city or metropolitan area. All categories must attend to gender and age, which thus becomes a fundamental aspect that is incorporated transversely in different items.

While it is an open source methodology, areas intended to be fixed while the category and all items are contextual and may be modified within the process of participation and discussion of proposals. Possible development of the matrix *[image 1]* on the next page is included.

The second step of the disaggregation categories are related to those major themes that define each of the four areas. The more disaggregated level corresponds to the item where specific aspects are collected to evaluate the intervention.

A visualization tool of the proposals, an instrument for participation

The matrix becomes a tool for discussion and participation of agents where priorities are displayed, on which aspects are involved and which are not. As such visualization tool should find a clear graphic image.

The matrix becomes a tool for discussion and participation of agents where you can prioritize and decide on concrete interventions. The tool allows you to display those aspects that are included in the proposal and those who are outside. As such visualization tool should find a clear graphical representation. For this reason, the matrix will be shown in a diagram ("Daisies") which is represented by a simple color code the qualitative assessment of the quality of each items, category or areas in the neighborhood. So the red color represents an unfavorable level; yellow an improved level; and blue, the acceptable level.

This may be applied at different stages of urban intervention: diagnosis, proposed and final evaluation of the results.



<p>[OUT] URBANIZACIÓN URBANO TERRITORIAL</p> <p>REGIONAL AND URBAN PLANNING</p> <p>OUT1 INTEGRATION AT FUNCTIONAL TERRITORY</p> <p>OUT 1.1. Functional territory mobility OUT 1.2. Infrastructures and city services OUT 1.3. Balance of public facilities OUT 1.4. Land uses OUT 1.5. Urban vulnerability</p>	<p>[DMA] DISEÑO URBANO Y MEDIO AMBIENTE LOCAL</p> <p>URBAN DESIGN AND LOCAL ENVIRONMENT</p> <p>DMA1 ACCESSIBILITY AND MOBILITY</p> <p>DMA 1.1. Structure of urban mobility DMA 1.2. Urban areas network according everyday uses and hierarchy DMA 1.3. Accessibility. Route Prediction Network DMA 1.4. Reinforced mobility (bicyc, pedestrian, car/mobility) DMA 1.5. Multimodal mobility (design and management)</p>	<p>[EOD] EDUCACIÓN</p> <p>BUILDING</p> <p>EOD1 BUILDING CHARACTERISTICS</p> <p>EOD 1.1. Typology and general characteristics of the buildings EOD 1.2. Functional programs of the buildings EOD 1.3. Types of clusters of buildings EOD 1.4. Ownership structure EOD 1.5. Relationship with the environment EOD 1.6. Constraints</p>	<p>[SES] SOCIOECONOMICA</p> <p>SOCIO-ECONOMIC</p> <p>SES1 SOCIAL AND INSTITUTIONAL NETWORK</p> <p>SES 1.1. Public resources SES 1.2. Private resources SES 1.3. Third Sector resources</p>
<p>OUT2 URBAN CENTRALITY</p> <p>OUT 2.1. Urban mobility OUT 2.2. Urban centrality OUT 2.3. Urban facilities networks at city scale OUT 2.4. Public spaces networks at city scale OUT 2.5. Urban vulnerability</p>	<p>DMA2 PUBLIC HEALTH AND WELFARE</p> <p>DMA 2.1. Public and natural demands for quality of life DMA 2.2. Hygrothermal comfort DMA 2.3. Ease of Use DMA 2.4. Environmental, noise and visual pollution DMA 2.5. Natural surveillance and neighborhood surveillance networks DMA 2.7. Security in relation to gender and age</p>	<p>EOD2 PHYSICAL FEATURES OF BUILDINGS</p> <p>EOD 2.1. Materials, products and systems EOD 2.2. Infrastructures and technologies EOD 2.3. Compatibility and coexistence EOD 2.4. Bioclimatic and hydraulic</p>	<p>SES2 ECONOMIC NETWORK</p> <p>SES 2.1. Local resources SES 2.2. Metropolitan resources SES 2.3. Social Economy SES 2.4. Internal Economy SES 2.5. Job SES 2.6. Quality in employment SES 2.7. Economic development opportunities</p>
<p>OUT3 URBAN VARIETY AND COMPLEXITY</p> <p>OUT 3.1. Diversity of uses and activities OUT 3.2. Diversity of types of buildings OUT 3.3. Urban facilities networks at neighborhood scale OUT 3.4. Urban public spaces at neighborhood scale OUT 3.5. Forms of appropriation of urban space</p>	<p>DMA3 URBAN LANDSCAPE AND SAFETY</p> <p>DMA 3.1. Beauty, cleanliness and order of the urban scene DMA 3.2. Heritage and Identity DMA 3.3. Readability and guidance systems DMA 3.4. Appropriate scale of public spaces DMA 3.5. Balance of public spaces DMA 3.6. Natural surveillance and neighborhood surveillance networks DMA 3.7. Security in relation to gender and age</p>	<p>ES3 SAFETY</p> <p>ES3.1. Structural safety ES3.2. Construction safety ES3.3. Fire Safety ES3.4. Safety in use</p>	<p>SES3 SOCIO-DEMOGRAPHIC STRUCTURE</p> <p>SES 3.1. Immigrant integration SES 3.2. Dependency SES 3.3. Structure and economic situation of households SES 3.4. Training SES 3.5. Social inclusion</p>
<p>OUT4 ARCHITECTURAL AND NATURAL HERITAGE</p> <p>OUT 4.1. Inventory of architectural and natural heritage OUT 4.2. Compatible uses with the preservation of their values OUT 4.3. Dissemination and visiting heritage. Identify and participatory processes</p>	<p>DMA4 PUBLIC SPACE STRUCTURE</p> <p>DMA 4.1. Diversity of types of open spaces DMA 4.2. Diversity of uses and activities DMA 4.3. Diversity of types of buildings DMA 4.4. Relation between ground floor and public space DMA 4.5. Promote of associations to assume environmental responsibilities</p>	<p>EOD4 HABITABILITY</p> <p>EOD 4.1. Minimum dimensional requirements EOD 4.2. Protection against noise EOD 4.3. Accessibility EOD 4.4. Outdoor relationship EOD 4.5. Thermal comfort EOD 4.6. Thermal comfort EOD 4.7. Acoustic comfort</p>	<p>SES4 RESIDENTIAL STRUCTURE</p> <p>SES 4.1. Tenure status of households SES 4.2. Adequacy of housing SES 4.3. Area available per inhabitant SES 4.4. Coexistence between communities SES 4.5. Empty and occupied dwellings</p>
<p>OUT5 URBAN METABOLISM</p> <p>OUT 5.1. Harvests of agriculture OUT 5.2. Atmospheric emissions OUT 5.3. Energy OUT 5.4. Water OUT 5.5. Solid urban waste OUT 5.6. Ecosystem services</p>	<p>DMA5 INFRASTRUCTURES AND LOCAL SERVICES</p> <p>DMA 5.1. Compliance of facilities and services (deficit and shortcomings) DMA 5.2. Energy efficiency of urban infrastructures DMA 5.3. TIC, garden 36 holes strategies, smartgrid DMA 5.4. Modular coordination between urban infrastructures and open spaces DMA 5.5. Water saving systems in buildings and public spaces DMA 5.6. Selective waste collection system. Accessibility to collecting places</p>	<p>EOD5 SUSTAINABILITY IN BUILDINGS</p> <p>EOD 5.1. Bioclimatic design EOD 5.2. Incorporation of renewable energy EOD 5.3. Heating systems efficiency EOD 5.4. Electrical installations efficiency EOD 5.5. Savings in water consumption and wastewater management EOD 5.6. Waste Management EOD 5.7. Life cycle analysis</p>	<p>SES5 RELATIONAL MANAGEMENT AND CITIZEN PARTICIPATION</p> <p>SES 5.1. Systems for citizen participation SES 5.2. Promotion of identity SES 5.3. Relationship between social actors at local level</p>

Image. 1

In 2011, the research group to which we belong (GIAU+S, UPM) with the group Tecnalia and caviar at the University of the Basque Country (UPV) in the “Diagnosis about intervention needs in the renovation of the building stock in the Basque Autonomous Community (BAC)” tendered by the Basque Government. The purpose of this project is to obtain an Inventory and Diagnosis of residential buildings, which were built before 1980 at the BAC, and its urban environment. The giau+s in this project developed an innovative methodology antecedent of the current for the development of comprehensive policies aimed at the rehabilitation and renovation of degraded urban areas. This methodology has been implemented in a pilot case, Zaramaga, a neighborhood of the city of Vitoria-Gasteiz, for which we have developed a specific intervention project. This proposal displays a similar system was used by the diagrams

(called daisies) for the diagnosis of the neighborhood and evaluate the impact of the Urban Integrated Regeneration proposal. [image 2]



Image.2: Daisies diagram. Zaramaga projec, diagnosis and proposals.

Following a series of works developed by the Research Group in Architecture, Urbanism and Sustainability of the Superior Technical School of Architecture of Madrid, the result of this research will be, on one hand, the design and assessment model described, and secondly, but not least, the establishment of a network of agents dedicated to urban rehabilitation, renovation and renewal, based on an web platform RE-HAB (<http://www2.aq.upm.es/Departamentos/Urbanismo/blogs/re-hab>), where the research findings will be published during the implementation of the project in order to increase knowledge and share experiences.

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New Concept for User-Orientated Suburb Renovation

Abstract: *Finnish national research project, User- and Business-oriented Suburb Renovation Concept (KLIKK), was started in January 2012 and will end in June 2014. The perspective of energy efficiency is emphasised in the project. The primary goal of the project is to develop a user-oriented, industrial, economic renovation concept for suburban apartment building renovation, extension and construction of additional storeys. The concept will make it possible to change from performance- and cost-based operation to novel service- and user-oriented, site-specifically tailored renovation methods utilizing integrated order and delivery chains.*

The user-oriented approach refers to both interactive planning that includes the residents in the planning process and construction techniques. Repairs to the shells of buildings are done with prefabricated elements which are fastened to the frame of the building from the outside. Balconies, lift shafts and additional storeys made of box elements are prefabricated as completely as possible and installed quickly and with little disturbance.

User-Orientated, Renovation concept, Prefabrication, Energy efficiency, Suburbs, Town planning

Introduction

Construction in the near future will focus on suburb renovation and in-fill construction, which will face a demanding challenge due to the objective of improving energy efficiency. The concrete-frame apartment buildings constructed in Finland in the 1960s and 1970s are approaching the age when they require renovation. These buildings contain significant share of the housing stock, making this a renovation job that affects a large share of Finns. (1)

Suburban apartment buildings require exhaustive technical repairs. For example, problems related to the quality of the concrete and the reinforcements of the sandwich elements used and the durability of the trusses and fasteners of the elements, moisture damage and poor thermal economy are the most common reasons behind façade renovations. Also the roofs, windows and balconies need repair or renewal. (2), (3) It is hard to find operators who are capable of or willing to take on suburban apartment building renovations, and it is often necessary to search for and hire several contractors for a project. It is very difficult to integrate their work. In practice, renovations are slow, expensive, dirty and disruptive.

Objectives of the Project

The main objective of this project (1.1.2012-30.6.2014) is to create a user-oriented, industrial, overall-economical and efficient renovation concept for suburban apartment building renovation and extension. The objective is to develop an industrial renovation concept where solutions can be site-specifically and all-inclusively tailored within the framework of a novel operating model that integrates suppliers and new rules of the game to be developed in the project, and implement those solutions by means of networked business operation. With standardised operating methods, methodicalness and manageability will reduce costs, improve quality and decrease dispersion.

Residents' choices are limited by their financial capacity, but improvement of their own comfort is most important. This requires various all-inclusive solutions that are correctly

focused also from the end user's (resident's) perspective. (4) Important from the standpoint of housing companies is the cost structure of the renovation project. Constructing an additional storey(s) may be a decisive opportunity for funding necessary façade and balcony renovation or building a lift. From the standpoint of real estate owners, alongside of selling permitted building volume it is necessary develop new types of financing instruments. These could be, for example, partial ownership of the real estate through supplementary construction and financing of supplementary or in-fill construction through leasing or so-called life-cycle model funding. (5)

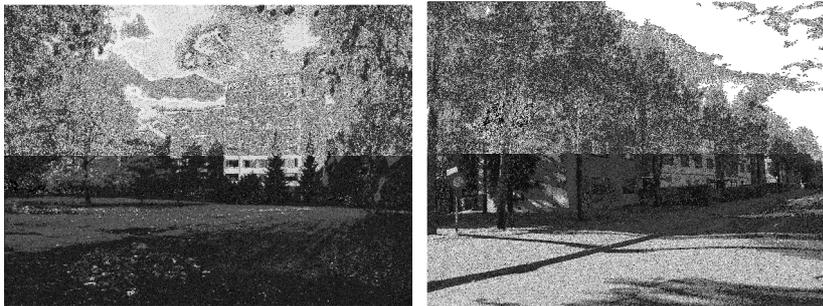


Fig. 1, 2. A significant number of suburbs were constructed in Finland in the 1960's and 1970's. The concrete-frame multi-storey apartment buildings are the dominant building type.

An objective of the project is to develop a less complex and more flexible zoning model for suburb renovation and in-fill construction in collaboration with participating cities, and simultaneously develop practices for environmental impact assessment tools to support and justify suburb in-fill and supplementary construction.

The objective in this User- and Business-oriented Suburb Renovation Concept research project is to compile a publicly available model book in collaboration with partner companies which will help housing companies start renovation projects by providing them with tools for user-oriented ideating and planning. The purpose of the model book is to present different types of all-inclusive solutions for block in-fill construction and construction of additional storeys atop suburban apartment building using box elements; energy-efficient renovation of the outer shell of buildings—particularly exterior walls—and façade renewal using various materials; construction of balcony systems and installation of lifts.

Parties of the project

The parties to the project consist of a wide range of Finnish universities, research institutions and companies in the construction sector. The participants are the University of Oulu's Department of Architecture and Department of Industrial Engineering and Management, Aalto University's Department of Architecture, Tampere University of Technology's Department of Construction Engineering and the Technical Research Centre of Finland. Participating companies include Stora-Enso, Isover Saint Gobain and construction companies. Other partners include several cities like Joensuu, Kouvola, Porvoo and Turku, real estate representatives, the Ministry of the Environment and the Finnish Real Estate Federation.

Energy efficiency and the renovation of facades

Energy efficiency is emphasised in the project. It is customary to improve the thermal insulation of the facades in connection with apartment building renovations in Finland. Ordinarily this is done by applying a coat of plaster on top of an additional layer of insulation or alternatively by removing the existing facade material constructing new, better-insulated facades(6), (7). Done in this manner, the work is expensive and slow and it disturbs the residents. A TES system (a timber based element system) is based on large, lightweight stick-frame elements which have been designed for facade renovations. The elements are fastened to the inner shell of the sandwich elements of the exterior wall, and due to their lightness they may be several storeys high (8). This type of system has already been used in two apartment building renovations in Finland—the INNOVA project in Riihimäki (9) and Kummatti in Raahe (10).

Large, lightweight stick-frame elements offer a promising renovation solution, so in this study we have concentrated on developing this solution to make it widely usable in renovations. The challenge with exterior wall elements is the airtightness and load-bearing capacity of the exterior wall, especially in cases where the existing building lacks a load-bearing inner shell or the facades consist of horizontal band elements. The frames of elements also require special strength analysis if the facade facing is very heavy, e.g. brick slabs or planks.

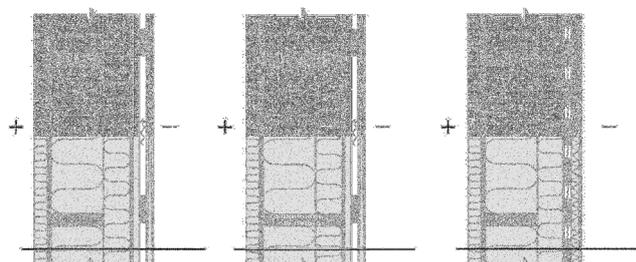


Fig. 3. Examples of TES system based stick-frame elements to be fastened to the inner shell of a building's concrete exterior wall elements. The facade can be made of plaster or ventilated cladding, for example. (Insinööritoimisto Tero Lahtela)

In this study we have designed renovation elements whose inner shell is made of self-supporting cross-laminated timber (CLT) panels. The CLT panels function as a load-bearing, stiffening layer in the element, but they also make the element airtight. And because of the excellent load-bearing capacity of the CLT panel, the facade facing can be made from practically any material. This is important because the renovation concept for suburb renovations must be such that building renovations completed within its framework can be done using various facade facing materials so that the architecture of the building is preserved in the renovation, but also so that alternatively the architecture and appearance of the building can be changed completely, if so desired (11), (8).

Additional Storeys

Constructing additional storeys is an attractive alternative in connection with apartment building renovations, and this is often done in Finland, especially in areas close to city

centres. In practice, though, construction has been difficult and costly, and for this reason in this study we are developing ways to utilize industrial prefabrication in construction.



Fig. 4, 5. Fabrication of CLT module elements. Additional storey realised using box elements on rooftop. Excerpt from the floor plan and south elevation with new balconies and surfacing of the exterior walls.

The frames of suburban apartment buildings built in the 1960's to 1980's will easily carry the construction of lightweight additional storeys allowed by the new fire code of Finland. To minimize disturbance inflicted on the residents, it is sensible to construct them from box like module elements. However, designing and constructing module elements is challenging because the top ceiling slab usually cannot be loaded, whereupon loading has to be aligned with load-bearing walls below the slab, which may be few in number. On the other hand, to increase floor area it may be desirable to make the top storey larger than those below it (12).

In this study we have examined the designs and dimensions of the load-bearing frames of typical suburban apartment buildings constructed in the second half of the 20th century and we have tested how additional storeys made of module elements can be constructed atop the frames. To avoid having the layout of the rooms in the additional storeys dictated by the layout of the rooms in the storeys below, we decided it is practical to make the module elements self-supporting. A modular element system with a load-bearing frame (walls, ceiling and floor) made of CLT panels has been designed in collaboration with Stora Enso.

Since the module elements are self-supporting, they can be installed so that the load-bearing walls of the elements either coincide with the load-bearing walls below or are perpendicular to them. Preliminary studies have revealed that another good solution is to install steel beams on top of the existing structure. This solution provides much freedom in designing additional storeys and in installing heating, plumbing and ventilation. The self-supporting structure of the module elements also makes it possible to extend the new, additional storey approximately 2 metres beyond the outer walls of the storeys below. Module elements can be quite large, but due to production, transport and lifting expenses, it is recommendable to limit element inside width to 4.2 metres, length to 12.0 metres and height to 2.95 metres. Due to acoustic and fire safety regulations rooms of two separate apartments can't be located in same module element. Sanitary rooms with wet sealing can't be divided in two adjacent module elements.

The results of the study will be tested in actual suburban apartment building renovations. The first pilot project is a block at Kirkkokatu 18 in Joensuu. The facades of two existing four-storey buildings on the block will be renewed using prefab brick-tile-faced self-supporting

elements whose energy efficiency meets the requirements for new construction. At the same time new prefab balconies will be installed. As part of the renovation plan, we devised a way to construct the additional floors of the building being renovated and a new building in the courtyard by utilising module elements.

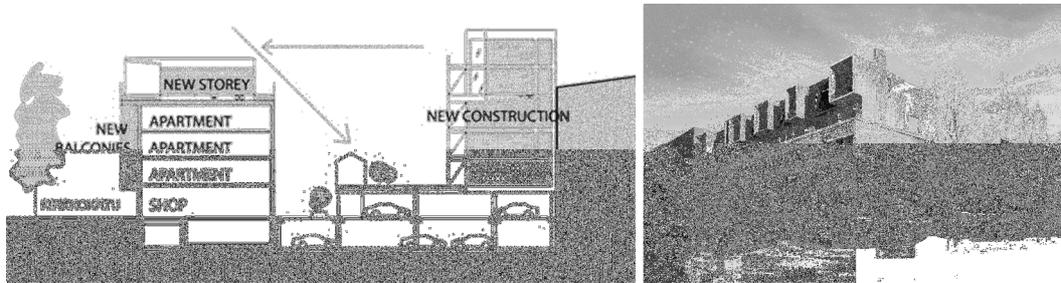


Fig. 6, 7. Additional story on top of an existing building and a new in-fill construction in the courtyard. (Petri Pettersson's master thesis, University of Oulu 2013)

In-Fill and Additional Constructing in Suburbs

The building stock of Finnish cities is for the most part located in suburbs, and in international comparison Finnish suburbs are very sparsely and inefficiently built. Indeed, Ministry of the Environment has set a goal to densify the structure of Finnish cities, and at the same time make suburban land use more efficient. The target sites for town plan analysis have been chosen together with the cities: two suburbs in Turku, two in Porvoo, two in Kouvola and one in Joensuu. The areas differ greatly in size and nature, so they form an excellent series in which they complement each other. Assessment of the environmental impact of the sites has begun and the re-planning work of each area is on-going.

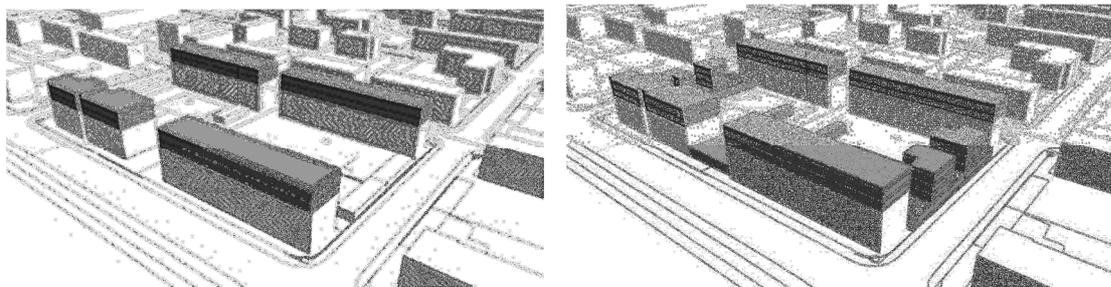


Fig. 8, 9. Additional stories and in-fill construction KLIKK-case study in Joensuu. New building volume is indicated by dark grey color. (Toni Pallari's master thesis, University of Oulu 2013)

In these suburbs there is a need to both densify the sparse structure of these areas by erecting new residential buildings to fill in existing blocks and construct additional stories atop existing residential apartment buildings in connection with their renovation. In many cases it is practical to apply both solutions on the same block, as indicated by an assessment of areas near the centre of city of Joensuu. New residential buildings not only raise the plot ratio but also make the existing sparse block structure more defined and improve the micro climate.

In this study we will examine whether the town planning procedure currently used in Finland is suitable for steering this type of supplementary and in-fill construction. The town planning procedure is laborious, and on the other hand supplementary and in-fill construction in



existing suburbs will take place over quite a long time. So, the project will develop a less complex town planning models for suburb renovation and in-fill construction. These less complex town planning models could be e.g. an areal exceptional permit process with construction method guidelines or a general area plan with loose specification of permitted building volumes, in which case exact construction methods and building volumes would be specified for each block in the building permit phase.

Conclusions

The project will develop a user-oriented, industrial, overall-economical and energy-efficient renovation concept for suburban apartment building renovation and expansion as well as construction of additional storeys and lift shafts using self-supporting module elements. These solutions will not be developed specifically for certain companies; the development work will be done with government research funding and the solutions are meant to be widely utilized in suburb renovation and development. This will directly benefit residents, housing companies and real estate owners by enabling speedier, neater and cheaper renovations than used so far. The concept will also offer housing companies the possibility to upgrade buildings and thereby increase their value and attractiveness.

To manage renovation costs, the development work will concentrate especially on wintertime construction, which would allow house factories to use their underutilized autumn and winter capacity. However, this places challenges on job site conditions, especially moisture control, which needs to be addressed in the study.

The project will promote suburb supplementary and in-fill construction which will help reinforce the areas' population base, thereby ensuring that services are preserved, which is in the interests of the residents and the suburbs. That will also be an effective tool to retard the sprawl of cities.

The results of KLIKK (User- and Business-oriented Suburb Renovation Concept) project benefit housing corporations in improving energy efficiency by offering new methods of renovation and retrofitting. Same time in-fill construction offers a possibility to finance the renovation and also a possibility to build new common facilities. The residents benefit from less intrusive renovation method than normally which minimizes the disturbances and can be realized without emptying the flats. Construction companies have possibility to create new know-how, a business model and marketable industrial solutions. New retrofitting methods can be applied globally as the industrially produced concrete-frame apartment buildings are common in many countries. Finally, the enhanced housing quality and declined energy consumption benefits the residents and housing corporations all over in cold climate.

Acknowledgements

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Evaluation and Development of Indicators for Sustainability Assessments of Urban Neighbourhood Renovation Projects

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Abstract:

This paper shows how a repository of sustainability indicators built up from existing rating schemes (e.g. LEED, DGNB, BREEAM, HQE), R & D projects (OPEN HOUSE, SuPerBuildings) and CEN/TC 350 standards on building and neighbourhood-level is evaluated regarding its suitability and feasibility to assess the sustainability of district retrofitting projects. To compare different retrofitting strategies with regard to energy savings and sustainability, it is necessary to select suitable Key Performance Indicators (KPIs). At the moment the majority of available sustainability indicators on the market are applicable to newly built buildings and districts only. This study identifies the main problems applying the existing indicators to district renovation projects. Moreover, it is shown how the indicators have to be adapted in order to generate meaningful results for a solid sustainability evaluation of urban district retrofitting projects. The developed KPIs are shown in the paper and will be used in the FASUDIR project [1].

Keywords: *Sustainability Assessment, Urban Neighbourhood Renovation, Retrofitting, Energy, Key Performance Indicators, Feasibility*

Introduction

The European project FASUDIR has been established under the framework of a FP7 R&D program by a European consortium of 12 partners from research institutions, software companies and municipalities. Running from September 2013 to August 2016, its objective is to develop a software that enables involved stakeholders in district retrofitting projects to compare and assess different retrofitting strategies with regard to the sustainability of the whole urban district [1]. To ensure usability and effectiveness, the software will contain a collection of sustainable retrofitting strategies and technical solutions at building and district level. Each strategy can be characterized according to achievable energy savings and different sustainability aspects using specially developed Key Performance Indicators (KPIs). The indicators will assess the project along its environmental, social and economic performance, with focus on resource efficiency, low emissions, health & comfort and cost efficiency.



Determination of indicator types for district retrofitting projects

It is necessary to evaluate the impacts of different energy retrofitting measures on the sustainability of each renovated building as well as on the sustainability of the whole urban district. Due to the fact that energy retrofitting measures can be conducted on both building (e.g. change of windows) and district level, (e.g. installation of district heating systems) it is necessary to measure the sustainability on building and district scale concurrently. Therefore FASUDIR uses three main categories of indicators that are operating separately on building and district level.

1. Indicators on building level (B)
2. Indicators on district level (D)
3. Multiscale indicators operating on building and district level (M)

Thus, it is possible to assess the changes in sustainability of single buildings in the district, as well as the overall sustainability of the whole district. Often retrofitting measures conducted on individual buildings are affecting the sustainability of the whole district. If there are interactions between the KPIs on building and district scale it is possible to use the same indicators with a multiscale approach. In these cases the KPIs on building level can be aggregated by summing up the results from the building level to an overall district KPI. For example, reducing the energy consumption of a single building will have an influence on the energy consumption of the entire district. This means that the same indicator can be used on building and district level as a multiscale indicator. Apart from that there are also KPIs on building level that are not affecting the sustainability of the whole district. For instance changing the windows of a single building may increase the thermal comfort of the individual building, but will have no influence on the thermal situation (e.g. heat island effect) of the entire district. In this case it makes no sense to use an aggregated indicator on building level to assess the corresponding issue on a district level. Instead a new indicator, assessing the thermal situation of the district, has to be developed and a multiscale approach will not be possible in this particular case.

Analysis of indicator suitability for district retrofitting projects

In the study, a first repository of indicators related to FASUDIR was built up from existing methodologies (e.g. LEED, DGNB, BREEAM, HQE), R&D projects (e.g. OPEN HOUSE [2], SuPerbuildings [3]) and CEN/TC 350 standards on building and district level. The repository provides more than 600 indicators for different building types (office, residential) and use patterns (newly-built, refurbishment) [4] [5]. The goal of the suitability analysis is to reduce the total of 600 indicators to a manageable, but still meaningful amount of key performance indicators that are sufficient for conducting a solid sustainability assessment of urban district retrofit projects (see image 1). While the indicators found in the different rating schemes, research projects and standards mostly have different titles and calculation methods,

they are still addressing the same sustainability issue.

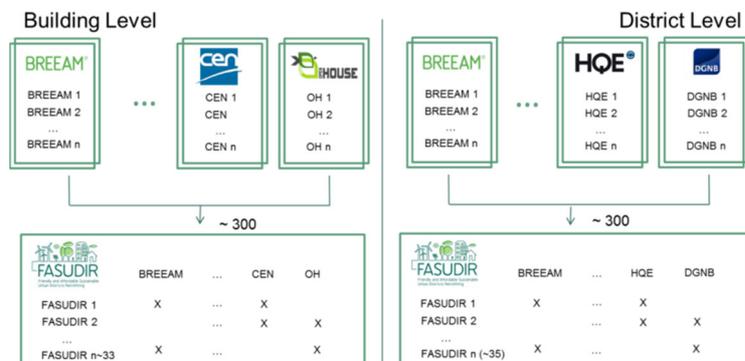


Image 1: Identification process of the main sustainability issues addressed by existing methodologies, R&D projects and CEN/TC 350 Standards

In the analysis, the main sustainability issues are addressed by the selected indicators and are ranked according to their suitability to district retrofitting projects (table 1). The following criteria have been used:

1. Rate of change of the issue due to energy retrofitting measures
2. Presence in existing methodologies, research projects and CEN/TC 350 standards
3. Input from Local Project Committees (Municipalities, Urban Planners, Building Solution Providers, Financing Institutes, etc.)
4. Application frequency for decision making in real European district retrofitting project
5. Individual experience of the different project partners

Table 1: Results of the suitability analysis for the different main sustainability issues identified

Rank	Building Level	District Level
1	Energy	Energy
2	User Comfort	Economic Framework Conditions
3	Costs	Land use / Demand of Space
4	Economic Performance	Mobility / Traffic
5	Health	Sociocultural Quality of the District
6	Environmental Impacts	Costs
7	Material Efficiency / Recycling Potential	Environmental Impacts
8	Water	Environmental Risks in the District
9	Design Quality	Functionality
10	Functionality	Technical Infrastructure in the District
11	Safety and Security	
12	Land Use / Demand of Space	
13	Biodiversity	

Analysis of indicator feasibility for district retrofitting projects

The first step of the suitability analysis provides a list of important sustainability issues for FASUDIR. Anyway, the significance of an issue implies not automatically the actual feasibility in the FASUDIR tool. The reason for this is that the data availability for existing buildings and districts is generally of poor quality. Hence, many parameters for the calculation of the indicators are missing or the effort for collecting data for whole urban districts is not feasible. In order to assess the feasibility of indicators linked to the selected KPI issues, an analysis of each indicator has been carried out. The analysis was based on the following criteria to evaluate the feasibility for FASUDIR:

1. Type of indicator (decision vs. information)
2. Type of calculation method (qualitative vs. quantitative)
3. Assessment method (simulation, calculation, reasonable deduction)
4. Needed parameters for assessment
5. Availability of simulation / calculation tools
6. Availability of data source
7. Easiness of data access for existing buildings

Summary and discussion of identified problems in the KPI feasibility analysis

Operational Energy Demand and Thermal Comfort:

Within the member states of the European Union several different energy calculation methods are used (e.g. DIN V 18599, CALENER, ASHRAE) [6]. All methods are adapted for each country specific requirements and are based on different calculation parameters (system boundaries, area types, reference climate data, etc.). Applying different methods on the same building, leads to widely varying results. In order to ensure the applicability of FASUDIR for all member states, the use of steady-state energy calculation methods is not possible. To obtain comparable results for the FASUDIR energy demand indicator, the only suitable way is the execution of building simulations. Simulations on district scale for large numbers of buildings are very time-consuming and need high computing power. The required time varies depending on the building models and the considered framework conditions. FASUDIR is operating on district level, which means that the simulations may be carried out for up to 1000 buildings. The application is only possible in an acceptable time frame by using simplified building models (one zone or floor by floor) and supercomputers. Moreover, the amount of required building data to conduct thermal simulations is high and not comprehensively available for existing buildings. To solve this problem, FASUDIR uses predefined building typologies which include default values for the main simulation parameters. Hence, the



accuracy of the simulations is still sufficient for FASUDIR requirements. The FASUDIR user has the possibility to change the parameters at any time if more accurate data are available.

Life Cycle Analysis Indicators (LCA and LCC):

The results of the analysis show that one of the main problems is caused by the lack of available country specific data for the LCA and LCC calculations on building and district level. LCA and cost databases for building products are already available in some European countries but not comprehensively within Europe. Especially the LCA and cost data for the energy infrastructure on district level e.g. construction of heat and electricity grids, energy storages or combined heat and power units is difficult to obtain. Moreover, the input format of the different available databases is often not consistent. Hence, the data interoperability between specialized life cycle software products and the different databases is rare. Despite the identified difficulties, the LCA and LCC indicators were integrated in FASUDIR in order to consider the whole building and district life cycle. To achieve the best possible results in the LCA and LCC calculations, FASUDIR allows the user to select between different integrable country specific databases and the European LCA database “eLCD”. Developments in the near future will improve the availability and interoperability of LCA and cost databases by defining uniform standards and integrating further building components on building and district level. To face future developments, FASUDIR will support the integration of user preferred databases. Nevertheless it has to be accepted that the results of the LCA and LCC calculations at this time may be unprecise due to the poor data availability. The LCA and LCC calculations are strongly influenced by the assumed constraints e.g. period of consideration, energy price increase rate and interest rate. Therefore these parameters have to be chosen very carefully.

Indoor Air Quality:

In existing rating schemes, this indicator is based on measurements of TVOC and formaldehyd concentrations in rooms. The effort of conducting measurements on district scale is untenable due to the high costs and required time. Furthermore, measurements are only feasible for the assessment of the current state of buildings and for this reason not convenient to compare the different retrofitting strategies in the planning phase. Moreover, a simulation of TVOC and formaldehyd concentrations in rooms caused by the different materials used in the retrofitting process is not possible at the moment. Hence, the evaluation of indoor air quality in FASUDIR is based on CO₂-concentration levels within the individual buildings that may be affected by energy retrofitting. For example the air exchange rate can be reduced by installing thermally insulated windows or ventilation systems.

Overview on the final developed FASUDIR Key performance indicators used on building and district level

Table 2 shows the selected KPIs for the sustainability assessment of urban district retrofitting interventions on district level in the FASUDIR project [7]. Indicators that are operating on a multiscale level (concurrently on building and district level) are marked with “M”.

Table 2: FASUDIR Key Performance Indicators for District Level

Category	Indicator	Sub-Indicator	
1. Environmental Category	D.1.1 Energy Demand (M)	D.1.1.1 Total Primary Energy Demand	
		D.1.1.2 Energy Demand in Operation	
		D.1.1.3 Energy Embodied	
		D.1.1.4 Share of Renewable Energy on Site	
	D.1.2 Environmental Impacts (M)	D.1.2.1 Global Warming Potential	
		D.1.2.2 Acidification Potential	
		D.1.2.3 Ozone Depletion Potential	
		D.1.2.4 Eutrophication Potential	
		D.1.2.5 Photochemical Ozone Creation Potential	
		D.1.2.6 Abiotic Depletion Potential Elements	
	D.1.3 Raw Material Input (M)	D.1.3.1 Raw Material Input	
	D.1.4 Land Use	D.1.4.1 Soil Sealing	
	D.1.5 Water Use	D.1.5.1 Intensity of Water Treatment	
	2. Social Category	D.2.1 Motor Transport Infrastructure	D.2.1.1 Parking Facilities
			D.2.1.2 Infrastructure for Innovative Concepts
D.2.2 Public Transport Infrastructure		D.2.2.1 External Accessibility: Railway Station	
		D.2.2.2 Internal Accessibility: Bus, Tram, Tube	
D.2.3 Bicycle and Pedestrian Lanes		D.2.3.1 Bicycle Facilities	
		D.2.3.2 Bicycle and Pedestrian Networks	
D.2.4 Accessibility		D.2.4.1 Barrier-Free Access to the District	
		D.2.4.2 Access to Services and Facilities	
		D.2.4.3 Access to Parks and Open Spaces	
D.2.5 Noise Level		D.2.5.1 Percentage of Building Area over Noise Limit	
D.2.6 Thermal Comfort		D.2.6.1 Outdoor temperature / Heat Island Effect	
D.2.7 Gentrification	D.2.7.1 Gentrification Index		
3. Economic Category	D.3.1 Life Cycle Costs (M)	D.3.1.1 Life Cycle Costs (LCC)	
		D.3.1.2 Investment Costs	
		D.3.1.3 Running Costs Energy	
		D.3.1.4 Running Costs Non-Energy	
	D.3.2 Return on Investment (M)	D.3.2.1 Return on Investment	

On building level the used key performance indicators for FASUDIR are based on the same three sustainability categories. The KPIs on building level measure beside the multiscale indicators the user comfort (thermal, visual, noise), indoor air quality (indoor CO²-concentrations) and the change in value of property to show the effect of the retrofitting



strategy on building level. The used assessment methods are based on existing methodologies [2] [3].

CONCLUSION

In the development of suitable and feasible Key Performance Indicators for urban district retrofitting projects many difficulties were encountered. The main challenge is to find a trade-off between the accuracy of the KPIs calculation results and the time effort of the data collection and data entry. To overcome this problem the only useful way is using fast data entry methods. The most suitable solution was identified to be the combined use of automatic data collection methods to capture the required parameters from GIS data and predefined building typologies. The use of supercomputers can reduce the required computing time for the calculation of the KPIs to an acceptable extent. Nevertheless by using default values and approximations for many calculation parameters uncertainties must be accepted and finally considered in the decision making process.

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How do we understand net positive neighbourhoods? Three perspectives

Abstract: In the past few years, and related to regenerative design, the term “net positive” has been gaining traction in architecture and urban planning as a way of dealing with complex urban environmental problems. Net positive development, as defined by Birkeland (2008), is design that increases or creates economic, social or ecological capital and that makes a positive contribution to ecosystem services. Designing how excess resources may be used beyond a site’s boundary is a very appealing notion, but one that is difficult to evaluate without the proper definitions, methods, and conceptual frameworks. Understanding definitions, metrics, and appropriate design processes will of course be necessary for moving the discourse on net positive design forward. This paper specifically looks at how to understand net positive neighbourhoods. It synthesizes key findings from the emerging literature on net positive design in North America and Europe, as well as literature from related domains, such as urban ecology, industrial ecology, and socio-ecological systems. Drawing from this literature, it provides three different understandings of net positive neighbourhoods.

Net positive development, regenerative design, net positive neighbourhoods, industrial ecology

Introduction

In 2013, one of the streams at the SB13 conference held in Vancouver, British Columbia aimed at pushing the boundaries of current practice to understand net positive buildings. Net positive design is an emerging concept that is implicit in regenerative design. The February 2012 special issue of *Building Research & Information* describes regenerative design as engaging stakeholders from the outset, restoring natural ecosystems, enhancing resilience, and creating ecological and social capital (Cole, 2012; Mang & Reed, 2012; DuPlessis, 2012). It strives for transformational, rather than incremental change and sets itself apart from conventional green building practices. Net positive design is design that increases economic, social or ecological capital and that makes a positive contribution to ecosystem services (Birkeland, 2008). While several authors at SB13 Vancouver acknowledged the emergence of new research in the areas of net positive energy and water at the scale of the *building* (see for instance McCarry, 2013), there is little research being done at the scale of the *neighbourhood* (Waldron, Cayuela & Miller, 2013). The emergence of neighbourhood scale green performance and assessment tools such as as LEED for Neighborhood Development (LEED ND), BREEAM Communities, Casbee for Urban Development, and the more recent Living Community Challenge 1.0 would suggest, however, that understanding net positive neighbourhoods will be fundamental for moving the discourse forward.

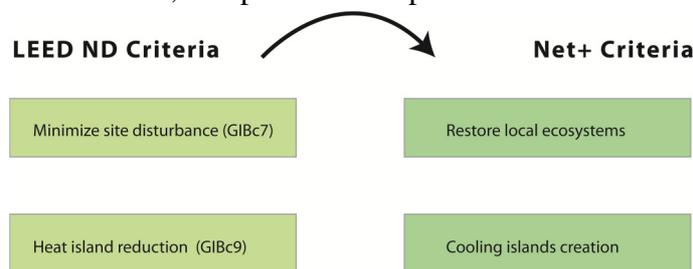
This paper’s primary concern is to understand net positive neighbourhoods. Designing how excess resources may be used beyond a site’s boundary is a very appealing notion, but

one that is difficult to evaluate without the proper tools, methods, and conceptual frameworks. The research methods of this paper primarily involve a literature review, drawing not only from emerging literature on regenerative and net positive design, but also from related domains such as urban ecology, industrial ecology, and socio-ecological systems. This paper proposes three different interpretations of net positive neighbourhoods based on three differing perspectives: metabolic flows, quantitative metrics, and social sustainability. The aim of this paper is not to propose something new per se, but to highlight the different lenses through which one can understand and define net positive neighbourhoods.

What are regenerative design and net positive development?

Regenerative design is based on *radical ecologism* (Tainter, 2012) and an analogy of buildings and cities as living systems. Rather than stopping at sustainable design, regenerative design calls for a full pendulum swing back towards ‘restorative’ and ‘regenerative practices.’ According to regenerative design proponents, conventional green building practices simply cannot create the *radical change* necessary for communities to thrive. As British architect, Peter Clegg (2012), explains, regenerative design asks practitioners “to produce built form and infrastructure that begins to ‘heal the wounds’ that have already occurred. It moves the bar higher...” (366) Pedersen-Zari (2012) notes that regenerative design “aims to create developments that are capable of restoring health to both human communities and the ecosystems of which they are part.” (p. 54) To summarize, regenerative design has, or at least aspires to have, the ability to ‘restore lost plenitude.’ (Van der Ryn & Cowan, 1996)

Several ‘principles’ of regenerative design have also been put forward by various authors (McDonough & Braungart, 2002; Thayer, 1994; Tillman-Lyle, 1994). The principle of net positive design is particularly attractive, yet it is in its infancy. Graphic 1 illustrates the differences between conventional green performance and assessment criteria, which aim at reducing negative impacts, such as reducing carbon emissions, materials that off-gas, or storm water runoff, and potential net positive criteria.



Graphic 1: Example of green versus net positive criteria. Source: author.

While from a metabolic flows perspective, which will be discussed later in this paper, progressive design closes loops, Birkeland (2007) and Plaut et al. (2012) argue that truly progressive design must take place in open systems, where many future options for design or re-design are left open. Though quite aspirational, Birkeland’s definition of net positive development nevertheless provokes several questions. Net positive at what scale and in what context? And net positive for whom? It fails to elaborate on other potentially important



dimensions of net positive design (such as waste treatment systems, water treatment systems, heating and ventilation strategies, and food production, to name a few). In an attempt to address some of these uncertainties, the next few sections of this paper will theorize net positive neighbourhoods from several different perspectives.

Net positive neighbourhoods from a metabolic flows perspective

What would a net positive neighbourhood look like from a metabolic flows perspective? In Industrial Ecology, industrial symbiotic relationships mimic the biological symbiotic relationships found in nature, wherein unrelated species exchange materials, energy, or information (Chertow & Ehrenfeld, 2012) and turn wastes at one point in a value chain into inputs at another point in a value chain (Mathews and Tan, 2011). Several authors from the discipline of Industrial Ecology outline the inputs and outputs that make up the built environment's 'complex system.' The primary inputs are: fuel, food, and water; other passive inputs include heat and air (Decker et al., 2000). This approach may also be used in neighbourhood and building design. Similarly, the 'flows and pathway approach' studies these inputs and outputs in order to diminish the ecological burden of a building, neighbourhood, or system on its surroundings (van Bohemen, 2012, p. 16). While in North America, closing loops and finding symbioses are often referred to as Cradle-to-Cradle design (C2C), in China, it is referred to as the circular economy or the "closed-loop" economy and has become an official development goal (Mathews & Tan, 2011).

In terms of theorizing net positive neighbourhoods, the most common example used in Industrial Ecology is the eco-industrial park – an area of collocated firms that shares streams of resources to enhance their collective efficiency (ibid). The neighbourhood scale therefore seems entirely appropriate from a metabolic flows perspective. Van Bohemen explains that industrial parks should be in harmony with surrounding natural systems and include "wetlands for cleaning runoff water from parking areas and reducing maintenance costs...native plants for the green areas around the buildings and other facilities... and increasing the ecological value of the site in connection with the ecological areas further away." (p. 55) In terms of energy flows, heated water or steam may be used by factories (or between factories or buildings) in an energy-cascading fashion. Similarly, in terms of material flows, waste products from one place may be a resource for another place (ibid). Hosseini & Cole (2013) propose that material flows are net positive when they have been recovered and reused several times (p. 27) and, moreover, contribute to occupant health & well-being. Their suggested baseline metric is new materials (ibid, p. 30). McDonough & Braungart (2013), who also study material flows, add that a closed loop is not net positive if the elements in the loop are toxic, emphasizing that "if you close the loops on an existing suboptimal design, then you're not truly Cradle to Cradle." (p. 44) The ultimate goal of the net positive neighbourhood is thus to create a zero waste environment with healthy materials (ibid).

Examples of eco-industrial park neighbourhoods include Kalundborg in Denmark; Kwinana in Australia; Suzhou Industrial Park and Tianjin Economic Technological Park in



China; and, Kawasaki in Japan. As many industrial areas (especially industrial ports) exist within dense urban fabrics, it seems appropriate to question why there are not more examples of industrial parks that have synergies with surrounding neighbourhoods. For example, waste heat could be captured in these industrial parks and used to heat nearby homes or schools. While further research is required to understand the closed loop / open loop debate in net positive design, Table 1 presents a possible definition of net positive neighbourhoods that builds on existing Industrial Ecology literature.

Perspective	Possible definition of net positive neighbourhoods
Metabolic flows	Neighbourhoods in which there is a positive exchange of materials, flows, and information between components (whether buildings, infrastructure, or systems), or between their components and those of an adjacent neighbourhood, and in which there is zero waste.

Table 1: Net positive neighbourhoods: an Industrial Ecology perspective. Source: author.

Building on the work of Mathews and Tan, a net positive neighbourhood from an Industrial Ecology perspective might therefore need to satisfy the criteria of: (1) a group of buildings as a whole make a positive contribution to ecosystem services and (2) where everyone benefits. This brings us to the second perspective: a quantitative perspective.

Net positive neighbourhoods from a quantitative perspective

While the previous section of this paper attempted to define net positive neighbourhoods based on an understanding of metabolic flows, this next section explores the role of quantitative metrics. Much work has been done on sustainability metrics and need not be summarized here. As net positive design is an emerging field, however, metrics have yet to become mainstream. We must therefore ask, what would net positive neighbourhood metrics look like? To this question, McDonough & Braungart (2013) answer: “How about *more* solar energy produced per hour? *More* water purified during the manufacturing process? *More* tons of tomatoes and greens being grown on urban rooftops?” (p.36) Recent literature (Bojic et al., 2011; Kolokotsa et al., 2010; Wang *et al.*, 2009), especially in Europe, has begun to explore the quantitative aspects (in terms of energy) of net positive design; however, most of this research is at the scale of the building. Zero energy buildings (ZEB) are broadly understood as buildings that consume as much energy as they generate in a year (Miller & Buys, 2012). As Marszal et al. (2010) explain, there is little international agreement on a ZEB definition, how to measure it, and what the period of balance is. These same authors distinguish between off-site supply, off-site generation, on-site generation from off-site renewables, and on-site generation from on-site renewables (p. 975). Positive-energy buildings (PEB), by contrast, are buildings that generate more energy than they need (Miller & Buys, 2012; Cole, 2013), and that also reduce energy demand. Cole (2013) outlines several potential differences between ZEBs and PEBs, including: PEBs may consider building energy and transportation energy in addition to operational energy; the time balance may be a life-cycle rather than one year; and energy quality may play a role in addition to energy quantity (p. 178). Renger,



Birkeland & Midmore (2013) even suggest that buildings may be able to sequester as much or more carbon than they used in the initial construction process (p. 94).

As well as considering the factors listed above, one must also consider different energy exchanges such as grid-connected systems, district heating, and energy scavenging (Cole, 2013). When considering this complex network of energy flows, it arguably makes more sense to consider net zero or net positive energy at the neighbourhood scale than at the scale of an individual building. To this point, Sartori et al. (2012) argue that a group of buildings may obtain an overall net zero condition, which individually may not necessarily be Net ZEB. Cole echoes this sentiment: “[N]et positive energy design should seek the maximization of energy performance in a system-based approach. As such, buildings, landscape, infrastructure and services must be considered as elements of a system/neighborhood collectively as being directed at providing the highest import-export and generation-consumption performance.” (Cole, 2013, p. 177) Table 2 proposes a simplistic definition of net positive neighbourhoods based on these arguments. More work, however, needs to be done to specify net positive neighbourhood indicators and evaluation methods.

Perspective	Possible definition of net positive neighbourhoods
Quantitative	Neighbourhoods that purify water, sequester carbon, and generate more renewable energy on-site than they need (> 100% energy savings). Neighbourhoods that do not contribute to peak demand and that increase the share of renewable energy on the grid.

Table 2: Net positive neighbourhoods: a quantitative perspective. Source: author.

Net positive neighbourhoods from a social sustainability perspective

While metrics may have an important place in architectural and urban planning arenas, it is nonetheless important to consider more qualitative aspects of net positive design. How, for instance, can neighbourhood design create social capital? One possible definition of a net positive neighbourhood is one that makes a positive contribution to its surrounding communities and thus not only satisfies “internal net positive criteria” but also “external net positive criteria.” From this perspective, not only are metabolic flows important, but so too are creative partnerships, temporary uses of vacant land, innovative and synergistic mixed uses, affordable housing, and support for the arts. The idea here is that – especially in new neighbourhood design or neighbourhood revitalization efforts – the new project not eat up all of a city’s resources and turn its back on surrounding communities (Pearl and Oliver, forthcoming). Social aspects of net positive neighbourhoods must therefore be understood both in terms of their design and their process. A net positive neighbourhood should provide social and cultural amenities for surrounding areas, instead of only focusing on its own internal needs. Moreover, in terms of process, true collaboration between all formal and informal stakeholders is required, and at all stages of the design process (see the ‘Governance’ category in BREEAM communities, for example). Multi-stakeholder collaboration is important in the later design stages in order to ensure an ‘ongoing



regenerative capacity’ (Mang & Reed, 2012). The design team in a new neighbourhood design or neighbourhood revitalization project should thus assist in uncovering win-win scenarios between the design site and its surrounding communities and in creating social capital (Pearl and Oliver, 2013). Forrest and Kearns (2001) suggest several domains of social capital of which net positive neighbourhoods could make a positive contribution: empowerment, participation, common purpose, support networks and reciprocity, collective norms and values, trust, safety, and belonging. Table 3 proposes a definition of net positive neighbourhoods based on a social sustainability perspective.

Perspective	Possible definition of net positive neighbourhoods
Social sustainability	Neighbourhoods that make positive social or cultural contributions to their surrounding communities and that foster win-win scenarios for all stakeholders.

Table 3: Net positive neighbourhoods: a social sustainability perspective. Source: author.

Discussion & conclusion

This paper has provided three alternative readings of net positive neighbourhoods. From a metabolic flows perspective, a net positive neighbourhood makes positive material, energy, and information exchanges between its components (buildings, infrastructure, or systems). From a purely quantitative standpoint, a net positive neighbourhood would simply be one that produces more renewable energy on site than it consumes and sells the surplus back to the grid. More research on other quantitative indicators (water, waste, heat, food supply), however, is required to advance the discussion on the quantitative aspects of net positive design. Finally, from a social sustainability perspective, a net positive neighbourhood is one that makes positive social or cultural contributions to its surrounding communities. Exploring understandings of net positive neighbourhoods from different lenses allows for complex issues to emerge -- for instance the array of requirements and possibilities that surface for PEBs in comparison to ZEBs. What becomes clear is that advancing the discussion on net positive design in general and net positive neighbourhoods in particular will require a lot more than new metrics, setting a time balance, and determining a baseline target. It will undoubtedly require a deep understanding of nested scales, of complex flows, and of synergies and trade-offs between different system components – issues that may need to be incorporated into the next generation of neighbourhood scale planning tools if they are to embrace the net positive agenda.

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Session 108:

Is it possible to define habitability conditions that insure healthy buildings without excessive spending?

Chairperson:

Zamora, Joan Lluís

Professor Universitat Politècnica de Catalunya

The Psychophysics of Well-being Socio-psychological Monitoring and Benchmark Measurement in Energy-efficient Housing

Speakers:

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Abstract: The exploration of subjective aspects in architecture mainly concentrates on life-style preferences and on issues of aesthetical and architectural psychology. In this research it is usually taken for granted that particular physical building parameters have positive effects on residents' well-being. Empirical research on what residents actually experience however and how they evaluate their housing environment in reality is rare. Following a two-years monitoring of the residents of the VELUX energy-efficient model home in Hamburg-Wilhelmsburg, Germany, the material gained from interviews and survey questionnaires in that process was analysed in order to uncover the underlying structure of housing well-being in energy-efficient housing and develop a multi-faceted measurement instrument that can be put to an empirical test with subjects from outside the model home. The goal is to design a Housing Well-Being Inventory (HWBI) that can serve as a standard for the measurement of the subjective quality of housing.

Keywords: Housing well-being, psychophysics, architectural psychology, energy-efficient housing

Introduction

In view of the problems of limited fossil energy resources, air pollution and climate change, it is essential to implement collective energy-saving measures and to use renewable energy sources that will also enhance reduction in CO₂ emissions. A key area for energy-saving is the housing sector. Using renewable energies and applying energy-saving technologies in residential housing will save countless tons of CO₂. However, energy-saving is not restricted to newly build houses alone. For economic as well as social and political reasons, new buildings cannot replace large proportions of the existing housing stock. In Germany for example, much of the present housing are "settler houses" dating from the early 1950s. These houses are simple constructions that were put up hastily after WW II to replace buildings that had been destroyed during the war. Their architectural design has long ceased to meet the needs of the current third generation of occupants. The challenge ahead therefore is to develop appropriate measures to upgrade the

energy systems to suit the needs of new groups of residents. To the extent that these needs are met, it will be possible to regenerate the settler housing stock, usually in peripheral urban locations, relieving the pressure on central inner-city areas and preventing at the same time undesirable land use in the surrounding countryside.

Renovation issues with regard to old settler houses involve different disciplines and professions. Not only architecture and engineering but also political science, psychology, sociology, urban planning, and health engineering all add important aspects that need to be taken into account. The study of these interdisciplinary aspects is only in its initial stages, both in terms of the availability of data and the development of theory. The focus of this report therefore is to examine the psycho-social domain of energy-efficient housing renovation or facets that can be treated in genuinely social-scientific terms. Our main object is the assessment of housing well-being and the person/environment interaction of housing.

The study of housing well-being must cope first with the representation of the concept of well-being as a multi-dimensional construct. In the present study, establishing such a construct has been the object of a two-years exploration phase with occupants of an experimental model home that was developed out of an old settler house. Secondly, this report outlines the methods used in the exploration of this concept and in its development. Thirdly, it presents the initial results of the exploration and allocates them to the components of the newly developed concept. Finally, using the concept thus explored and based on methods proposed recently by Wegener [1] for designing a standardized instrument for measuring well-being, it provides an overall evaluation of the measurement device.

Housing Well-being as a Multi-dimensional Construct

We propose a multi-component view of the person/environment interaction and of housing well-being conceiving it in terms of well-established psychological attitude models. If housing well-being is understood as an attitudinal phenomenon, it needs to be based on a definition of attitudes that stresses the evaluative element in attitudes [2]. Thus an attitude is understood as an individual mental evaluation of objects that is reflected in different dimensions. In the present case we employ a three-component view on attitudes originally developed by Rosenberg and Hovland [3] distinguishing between affective, cognitive, and conative reactions in attitude formation. These reactions can manifest themselves verbally as well as non-verbally. For both, measurement instruments can readily be built.

In application to housing well-being we are dealing with a mental construct that represents an evaluative judgement *over time*. Imagine that at time t_1 the residents are moving into their new home. At this point they develop a certain evaluating attitude towards their new home that we measure by means of verbal and non-verbal indicators. The judgement at t_1 however is influenced, among other things, by experiences individuals made at t_0 , i.e. before they moved into

their new home. Conversely, by t_2 time has elapsed in which the occupants have interacted with their new home affecting their evaluation anew. This dynamic interaction between the evaluation at t_0 and the various stimuli of the new home (e.g. temperature, functionality, social interaction) produces reactions in the dimensions of affect (triggering certain feelings), cognition (giving rise to certain opinions) and conation (influencing actual behaviour). These reactions can be measured at t_2 , but on-going experiences may alter this evaluation again, so housing well-being is certainly a quantity that needs to be re-measured at times t_3 , t_4 and so on in repetition. It can safely be assumed however that these changes level off after a while when the number of new impressions in a home decrease, giving way to a more stable well-being estimation.

Method

Since there is little relevant research to rely on, in our study the well-being of housing was carefully explored in an experimental study. The opportunity for this was provided by the VELUX LichtAktivHaus (LAH) in Hamburg-Wilhelmsburg, Germany, as part of the International Building Exhibition (IBA) and its numerous architectural, social and cultural ventures. The VELUX IBA project belongs to a series of pilot projects (“ModelHome 2020”) run by the VELUX Corporation. One of the goals of the VELUX project is to gain experience with regard to renovating existing houses according to energy-efficiency standards. During these experiments the model homes are closely monitored both in terms of physical performance and of the psycho-social functioning of the occupants.

In the Hamburg VELUX model home, a family of four—mother, father, two sons aged 5 and 8—were given the opportunity to take part in a real-life test of the building. They moved into the house by December 2011 and stayed on for more than two years (April 2014) when the experiment ended. (Actually in the end, the family decided to buy the house—post-experimentally, so to speak—and is still living there today.)

The study design for monitoring the test-family followed the sequential steps for developing standardized measurement instruments of well-being along different problem fields (as outlined by Wegener [1]). This begins with exploring the relevant dimensions of housing well-being. Several methods were used for this exploration: initial group discussions with the family members, self reports using diary methods, digital logbooks as well as a public family blog the family had fun to entertain. In addition, approximately every four weeks respondents completed an online questionnaire including both standardized and open-ended questions about the various dimensions of their well-being. About every six weeks, in-depth structured interviews were conducted with the parents in the form of video calls. Finally, extensive structured face-to-face interviews were carried out in the model home itself at the end of the yearly seasons. These different procedures led to the accumulation of a very detailed recording of the affective,

cognitive and behaviour-related dimensions of the family's well-being in the house.

Subsequently, this material was analysed in order to uncover the underlying structure of housing well-being that would then be put to an empirical test with subjects from outside the model home, the goal being to design a measurement instrument, the Housing Well-Being Inventory (HWBI), that can serve as a standard for the measurement of the subjective quality of housing.

Patterns of Exploratory Findings

1. Affective – Feelings and Perceptions

We began by outlining the *sensory imprints* of the family in order to become familiar with the affective components of attitudes. We distinguished four sections (thermal, hygienic, acoustic and visual perception) based on the influencing factors currently used in architecture to normatively characterise levels of comfort.

The thermal aspect includes the perception of temperature, air draught and humidity. Whereas the occupants perceived the temperature in the individual LAH rooms to be neutral during the initial winter months, at the beginning of summer they tended to describe the room temperature as somewhat too warm. During exceedingly bright sunshine periods in summer, the air in the rooms was found to be uncomfortable and too hot, so that additional manual ventilation was applied. In Figure 1, subjective temperature sensations are plotted against the objectively recorded room temperature and the range of the outdoor temperature in 2012.

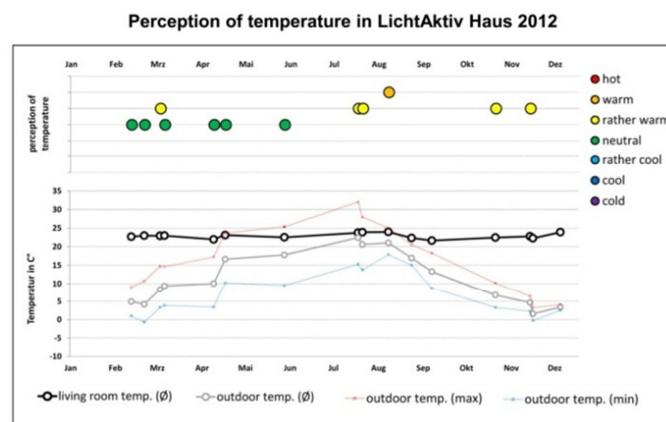


Figure 1: Temperature and temperature perception

Regarding *hygiene* in terms of air quality, a distinction had to be made between the children's rooms in the house and the other rooms. In the case of the latter, the occupants found the air quality to be very good throughout the year with no unpleasant smells, but in the children's rooms the air quality was sometimes less than satisfactory. These rooms were stuffy, especially in the mornings. This fault was possibly due to the low ceilings of the children's rooms, the lacking possibility of transverse ventilation and the fact that the air conditioning system was routinely turned down over night.

The perception of the *acoustics* was also recorded. The respondents were asked not only about external noises, such as street noise, but also about the noise caused by the in-house equipment as well as the efficiency of soundproofing within the building. External noises that were mentioned included the nearby railway and also the nearby motorway. These noises were not considered particularly annoying as the family quickly became accustomed to them. However, the noise from appliances, or more precisely the automatic opening and closing of the windows, was perceived increasingly loud and was felt upsetting throughout.

As far as *visual perception* is concerned, it is primarily the light supply in living areas that is relevant. The occupants of the LAH were often impressed by the amount of daylight in the house and saw this as a very positive aspect. The brightness of the rooms was applauded, not only in the summer but also in the darker months, so that even in the winter it was possible to manage without artificial light for long periods of the day.

2. Cognitive – Thoughts and Values

The study revealed many illustrative findings regarding the *cognitive components* of the well-being attitudes. For example, the functionality of the technical equipment, i.e. the interaction between persons and the technical environment in the building, played an important role in the evaluation of the LAH. This is true not only regarding the general operation of the building's technical systems but also for problem-solving strategies and the practicability of standard values. Generally speaking, occupants' feedback about the technical systems was very positive. In their eyes, the equipment worked perfectly. We also observed that over time the occupants became more familiar with handling the equipment and gradually learned to use the many different settings.

Automation is a valuable asset since it prevents incorrect ventilation, for example. However, family members did not really acknowledge the need for automatic air conditioning overnight and preferred undisturbed sleep to optimum air quality. Thus at no time did the occupants feel controlled, because they always had the sense that they could override the technology if necessary.

Since the architecture of the LAH is important for the comfort and satisfaction of the occupants, the outer appearance of the house was also included in the evaluation process. Again this was rated very positively and the occupants not only liked the external appearance of the house but also its internal layout and architecture. The occupants particularly enjoyed the size of the house and the availability of space.

Monitoring environmental awareness and the energy-consumption behaviour of family members brought to light particularly interesting aspects of the evaluation. It was assumed that moving into the LAH and the interaction with it, would lead to greater awareness and stimulate a more sustainable way of thinking. And indeed this assumption was confirmed. The occupants of the LAH grew more accustomed to energy consumption issues along the way. Obviously living in the LAH had a positive influence upon their environmental awareness.

Interviews with the family also revealed that their housing preferences had changed significantly over the course of the experiment. Whereas at the time they moved in, the extra space they gained compared with their old flat was seen as the most important feature of the new home, the longer they stayed in the model home, the more they appreciated its brightness, the garden and the energy-efficiency of the house. Initially occupants attributed this enhanced quality of living primarily to the modernity and the size of the house but within a few months they regularly referred to the brightness of the living areas as a contributory factor to their increased sense of well-being. In response to the question of what their main criteria would be when looking for a new house in the future, the family did now add brightness and energy-consumption as top priorities to their list of criteria. Obviously housing preferences are prone to changes if confronted with positive experiences.

3. Conative – Behaviour and Intentions

The third component of the attitude concept relating to housing well-being is the actual behaviour triggered by the attitudes. Managing the technical systems for controlling light, heating, air flow and energy-consumption is one of the activities within the realm of the person/environment interaction that was new to the family. But from the very start of the experiment, they were thrilled with the systems and the possibilities of controlling them. As they became more familiar with the techniques and the modification options, they also became more aware of system malfunctions and were able to identify problems quickly.

Great attention was also given to the family's *room usage* behaviour. Here, the large living area

was identified as by far the most often used room. It was the main recreation room used for various activities throughout the year. Because of its spaciousness and brightness, it was particularly inviting for social activities and for receiving guests.

There were also changes in the social interaction within the family after they had moved into the LAH. Essentially, the new home has had a beneficial effect upon the social climate within the family. This is not only evident amongst the children, who are now considerably more relaxed and squabble a lot less than in their previous home, but also in the improvement in the occupants' overall mood ("it all seems right somehow"). Their new home also changed their contact behaviour with friends. The main reason for this seems to be the additional space and the garden, which enable them to receive guests, so that they have had more social events in their own home since moving into the LAH.

Measuring Housing Well-being

The results of the two-years long exploration efforts, examples of which were given above, were then used to design a multi-dimensional device for measuring housing well-being. The purpose of this instrument is to have a yardstick for assessing the quality of a house as it is seen through the eyes of the users. How do houses, in particular reconstructed energy-efficient houses, perform socially and psychologically? What level of subjective well-being do these houses convey? Based on the explorations in our test family, we were able to accumulate a pool of roughly 250 questionnaire items that represented the categories of well-being that had proven to be important to the family of the LAH model home. The methodological task, if confronted with such a collection of survey items, is to reduce this excess of data empirically. The standard way of doing this is to have a sample of respondents answer all of the questions in the pool on a metric scale (from "very strongly agree" to "very strongly disagree," for instance) and analyse the resulting correlation matrix statistically. Using the factor analysis method [4] it is possible to disaggregate a correlation matrix into a small number of factors that emerge when one looks at the correlations of the questionnaire items with these factors. The factors with the highest correlating items are taken to be the most meaningful factors in representing the data in the correlation matrix. Conversely, the items that exhibit the highest correlations with the individual factors can then be selected for constructing a survey questionnaire.

Table 1: HBWI factor and factor loadings (factor loadings < .50 not shown)

	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
1. I have a positive attitude toward my apartment*	.84									
2. I feel at home in my apartment	-.94									

3.	I don't really like to be in my apartment	-0.84		
4.	I have difficulties calling my apartment my home	-0.96		
5.	My apartment is too small	-0.90		
6.	My apartment meets my need for ample spacing	0.90		
7.	I wish I had more room because everything is happening at one and the same spot	-0.90		
8.	The technical equipment in my apartment satisfies my need for modernity	0.80		
9.	My apartment is in need of renovation	-0.66		
10.	The technical equipment in my apartment is up to date	0.91		
11.	In my apartment I can make full use of the natural light	0.88		
12.	In my apartment I am too much dependent on artificial light	-0.90		
13.	My apartment has too many dark rooms	-0.78		
14.	On sunny days I can enjoy the light in my apartment to the full	0.78		
15.	I have nice neighbours	0.83		
16.	I feel accepted by my neighbours	0.97		
17.	My neighbours discriminate against me	-0.63		
18.	The temperature in my apartment can easily be adjusted according to my needs	0.73		
19.	The control of temperature levels in my apartment is satisfactory	0.91		
20.	During the winter months I have to adjust the temperature in my apartment quite often	-0.52		
21.	I sometimes wonder if my apartment uses up too much energy	-0.77		
22.	Cost for energy in my apartment is too high	-0.78		
23.	Compared to other apartments, the cost for energy in my apartment is low	0.84		
24.	My window panes often grow damp	0.83		
25.	I have a problem with mould-infested rooms in my apartment	0.76		
26.	Where I sleep there is too much light	-1.07		
27.	The sleeping environment in my apartment gives me a restful sleep	0.52		

28. My apartment can easily be ventilated	.96
29. I wish the temperature in my apartment could be controlled more automatically	-.65

*The reference “apartment” is replaced for “house” in appropriate applications.

The 250 well-being items of our exploratory study were presented to a sample of 60 sociology students who gave their responses that were then aggregated into a correlation matrix. The correlation matrix was factor analysed. Very much in accordance with our intuition from the exploration study, we find 10 meaningful factors based on 29 items. Each factor is marked by either two, three or four items that measure that factor. Together the 29 items form the core of the *Housing Well-Being Inventory* (HWBI) that presents the results of our study. Table 1 reports the main factor loadings (factor-item correlations) that characterise the 10 well-being factors and the item wording. They factors are named accordingly: Factor W1: *Emotional attachment*, Factor W2: *Size*, Factor W3: *Modernity*, Factor W4: *Brightness*, Factor W5: *Neighbourhood*, Factor W6: *Heating control*, Factor W7: *Energy consumption*, Factor W8: *Humidity*, Factor W9: *Sleeping comfort*, Factor W10: *Ventilation*.

The final version of the HWBI will have to include additional elements, among them are housing preferences [5], ecological awareness [6], life style inclinations [7], and engineering styles (König 2010 [8]). For most of these concepts however, there are numerous measurement instruments and survey questionnaires available on which our further research can rely. The same is true of course for the assessment of the socio-demographic information of the house users. In a modular combination therefore, the final product of the HWBI will consist of several subscales and categorizations.

Conclusion

Architects and engineers usually think that they are quite well informed about what the users of the houses they are constructing like. There are defined “ranges of comfort” with respect to temperature and light, air quality and acoustics that practitioners take for granted. Many of these standards have been implemented in formalised “social performance” guidelines—on the European level for instance in the CEN TC 350 norms *Sustainability of construction works* EN 15643-3 and EN 16309. But empirical research on what residents actually experience and how they evaluate their housing environment in reality is rare. Instead architects and lawmakers entertain a normative architectural psychology bias, stipulating future users as to what is good for them. We report here on an initial attempt to let the users have a say on what determines their well-being in the house. Following a two-years monitoring of the residents of the VELUX energy-efficient model home in Hamburg, the material gained from extensive interviews and

survey questionnaires was analysed in order to uncover the underlying structure of housing well-being in energy-efficient housing and develop a multi-faceted measurement instrument that can be used with subjects from outside the model home. The *Housing Well-Being Inventory* (HWBI), the core of which is presented here, needs refinement and further validation, but in its final stage the hope would be to have an instrument available for the benchmark measurement of housing well-being that will assist architects in building houses worth living in.

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Towards a fuel poverty definition for Spain

Speakers:

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Abstract: *During the last years, an increasing interest has been developed so as to address the problem of fuel poverty which is already affecting a huge number of European citizens. In 2013, the European Parliament has claimed to the Commission and State Members through several resolutions, the legislative development of policies in order to tackle energy vulnerability of households. In 2000 the UK Government, through the Warm Homes and Energy Conservation Act, established that a person could be regarded as fuel poor if he is a member of a household that cannot get warmth at a reasonable cost.*

Nevertheless, in order to establish the incidence of fuel poverty among Spanish households, it must be understood which should be the adequate thresholds for indoor temperatures. The research here presented proposes new indoor temperature thresholds for fuel poor households based on adaptive comfort models.

Keywords, *Fuel poverty, adaptive comfort, low income households, Spain, comfort gap*

Introduction

The present research falls within European interests on fighting poverty through the development of an inclusive economy with a strong emphasis on job creation and poverty reduction (1). Furthermore, recent UE documents encourage the State Members to develop their own methodologies in order to quantify fuel poor households (2), propose the creation of an European Fuel Poverty Observatory or even the establishment of housing energy retrofitting actions as a priority in energy efficiency EU programmes (3).

Within this context, the present research attempts to push forward the establishment of a definition of fuel poverty for Spanish households through the delimitation of the adequate indoor temperatures. This paper presents first results of the implementation of the proposed method in a building block.

Fuel poverty and indoor thermal comfort

Fuel poverty has been defined as 'the inability to afford adequate warmth in the home'. It can be appraised in households through the Fuel Poverty Index in which the three factors that cause it are reflected: housing lack of energy efficiency, high energy bills and low household income.

$$\text{Fuel Poverty Index} = \frac{\text{energy consumption} \times \text{energy price}}{\text{income}}$$

In that equation, the most difficult factor to measure is the energy consumption of dwellings which includes besides heating costs, domestic hot water, lighting, equipment and cooking. United Kingdom methodology sets the adequate level of warmth in 21°C for living rooms and 18°C for the rest of the rooms (4). These temperature thresholds are based on recommendations done by the World Health Organization (5) due to health risks derived from living in cold homes.

However in order to develop a fuel poverty definition for Spain, it must be doubted the suitability of these temperature thresholds for Spanish householders. On one hand, there has been scientific evidence of diseases and mortality rates related to high temperatures for years (6), a strong relation which was definitely highlighted by the heat wave of 2003. Thus, cooling needs must be included in the delimitation of the *adequate temperatures*. On the other hand, it is well known that the temperature at which mortality increases, differs from one population to another due to the adaptation of people to the weather they live (7). Hence, this supports that the adequate indoor temperatures must be adapted to the Spanish weather conditions.

Besides that, given the poor energy performance condition of low income households added to the lack of heating or cooling systems (8), as it can be seen in Figure 1, makes the adequate temperatures unaffordable for them. This means these households are likely to suffer from extreme hot and cold temperatures which make it urgent to develop a methodology so as to evaluate their indoor thermal conditions.

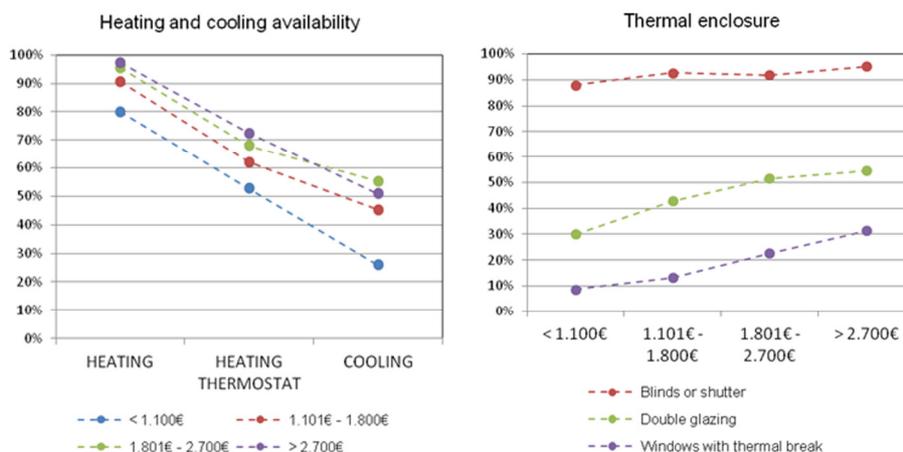


Figure 1 Left: Heating and cooling availability of households in the Autonomous Region of Madrid according to their monthly income level. Right. Energy efficiency measures in households in the Autonomous Region of Madrid according to their monthly income level. Source: Sanz,A., Sánchez-Guevara, C. et al. 2014.

Nowadays, the evaluation of indoor thermal conditions in buildings has evolved from static models developed by Fanger and gathered in the ISO 7730 (9) to a dynamic approach based on adaptive models: the one gathered in CEN 15251 (10) developed by Humphreys and Nicols and the other one collected in the ASHRAE 55-2010 (11) carried out by de Dear.

Adaptive comfort model is based on field research and establishes the dependency of occupants' thermal comfort of the external temperature. The ASHRAE model, based on an extensive field work conducted in numerous countries around the world, sets the operative comfort temperature (T_{ot}) as follows:

$$T_{ot} = 0.31T_o + 17.8$$

Where T_o is the mean external temperature of previous days (between 7 and 30 days). Furthermore, the model establishes two comfort zones; the first one, for the 90% of acceptability ($T_{ot} \pm 3.5^{\circ}C$) and the second one for the 80% of acceptability ($T_{ot} \pm 2.5^{\circ}C$).

Materials and methods

a) The case study is a linear building block from the neighbourhood of San Cristóbal de los Ángeles. It is located in Madrid, whose climate is classified as a D3 according to the Código Técnico de la Edificación.

This neighbourhood was identified as a vulnerable neighbourhood (12) and the indicators that made it vulnerable were a 25.5% of illiterate or with no studies population, 1.5% of houses with no toilet and an unemployment rate of 20.89%. According to that report, the majority of the population living in these neighbourhoods are sheltered in dwellings built between 1960 and 1975.

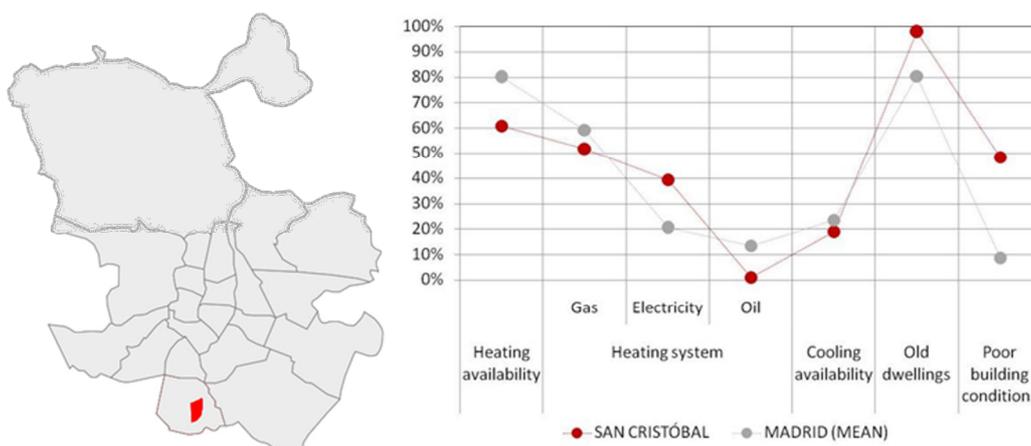


Figure 2 Left: location of San Cristóbal de los Ángeles in the city of Madrid. Right: dwelling characteristics comparison between San Cristóbal and Madrid mean values. Source: personal compilation from 2001 Census data.

Detailed data from 2001 census, plotted in Figure 2, shows some shortfalls in the neighbourhood housing stock compared to the mean values of Madrid, in line with what was

pointed out in Figure 1. As it was expected, this neighbourhood, with a low socioeconomic level, suffers from some building deficiencies as well, such as lack of heating and cooling systems, the dependency of energy sources such as electricity with likely increasing prices, an old housing stock mainly built before first energy efficiency regulations (CT-79) and in bad conditions.

Figure 3 shows the neighbourhood floor plan, formed by the most common dwelling typologies of this period: linear and H shaped building blocks. For this research advance a type of linear block is presented. The single block consists of five floors with two flats for each staircase and it forms larger blocks through the addition of blocks. Figure 3 shows floor, facade and section plans and Table 1 presents the envelope thermal characteristics.

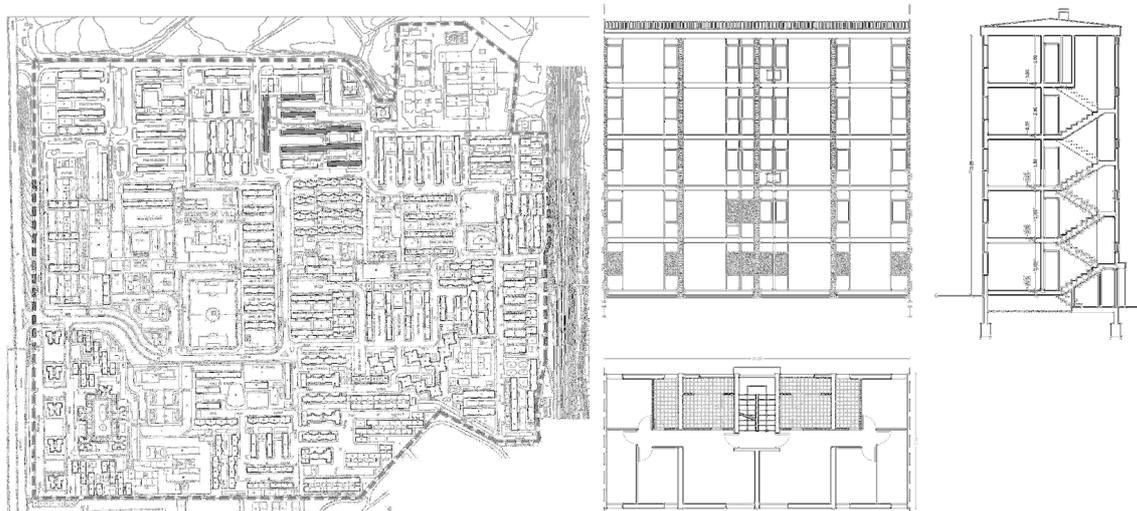


Figure 3 Left: Neighbour floor plan with the analysed block in black. Right: Floor, main facade and section of the studied building block.

Table 1. Building envelope thermal characteristics

Envelope	External walls	Roof	Floors	Windows (glass)	Windows (frame)
U value (W/m ² K)	2,76	2,36	2,28	6.12	5,26

b) Dynamic thermal simulation was performed in the Energy Plus 7.0 modelling software. Each dwelling was divided into two thermal zones, rooms and daily living spaces, in order to achieve a better appraising of indoor thermal comfort. Internal gains values regarding occupants, equipments and lighting were set like those used in energy labelling software (Herramienta unificada LIDER-CALENER). The model was evaluated in a free running mode and natural ventilation through windows was set during night summer time. Besides that, the most representative dwellings within a north-south and east-west oriented blocks were appraised.

c) Indoor comfort temperatures were set through the adaptive comfort model gathered in ASHRAE 55-2010 for naturally conditioned spaces. The mean outdoor air temperature was set as the mean value of the last 7 days temperature. Both comfort temperature thresholds

were studied: the 80% of acceptability for general householders and the 90% for those regarded as more vulnerable such as children, elderly and sick people. Figure 4 shows the comfort thresholds developed for de weather of Madrid.

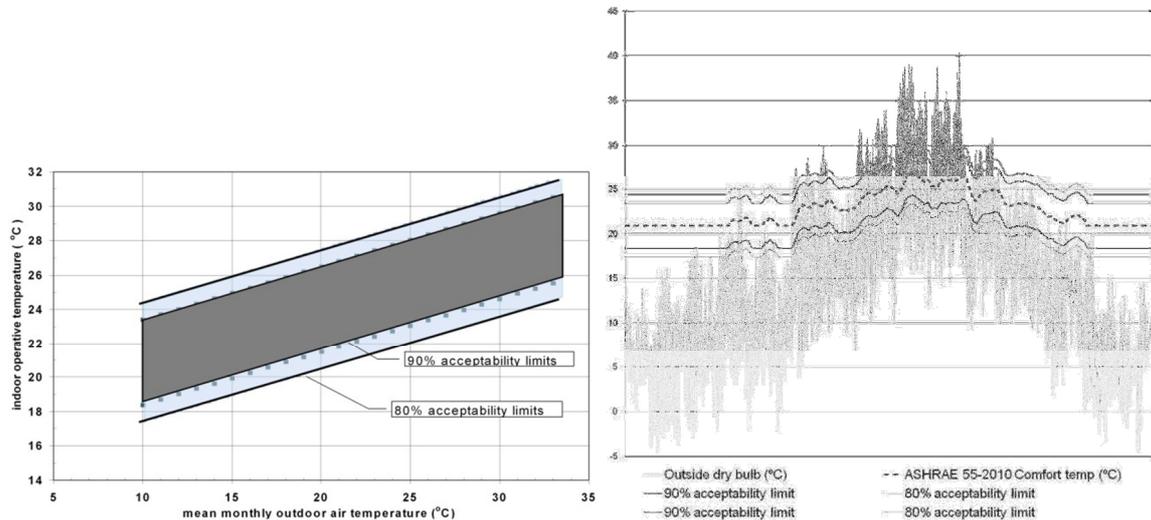


Figure 4 Left: Acceptable operative temperature ranges for naturally conditioned spaces (11). Right: Comfort thresholds for Madrid weather calculated according to ASHRAE 55-2010 adaptive comfort model.

Results

Room and living space indoor temperature results were compared against calculated comfort temperatures as it can be observed in Figure 5. For the coldest period, where the mean weekly outdoor temperature was lower than 10°C, comfort temperatures were considered constant and minimum values.

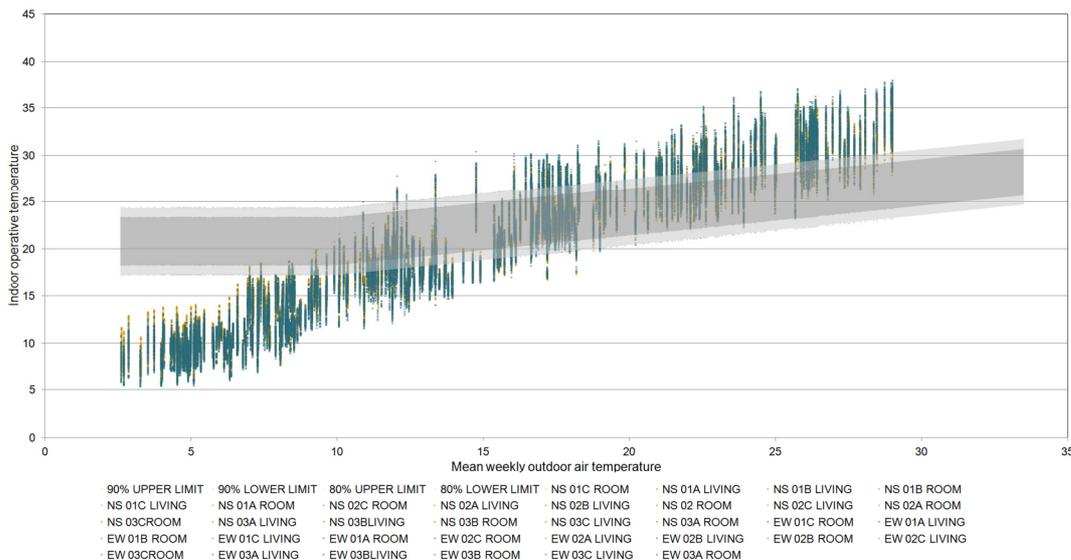


Figure 5 Dwelling indoor temperatures along with calculated comfort temperatures.

In order to get an accurate appraising of indoor thermal comfort conditions, the degree hour criteria gathered in EN 15251 was utilized. This method takes into account not only the number of occupied hours that are out of the comfort range but the degree of discomfort

which is measured with the difference between the actual temperature and the comfort threshold. This is what authors have defined as the *comfort gap*.

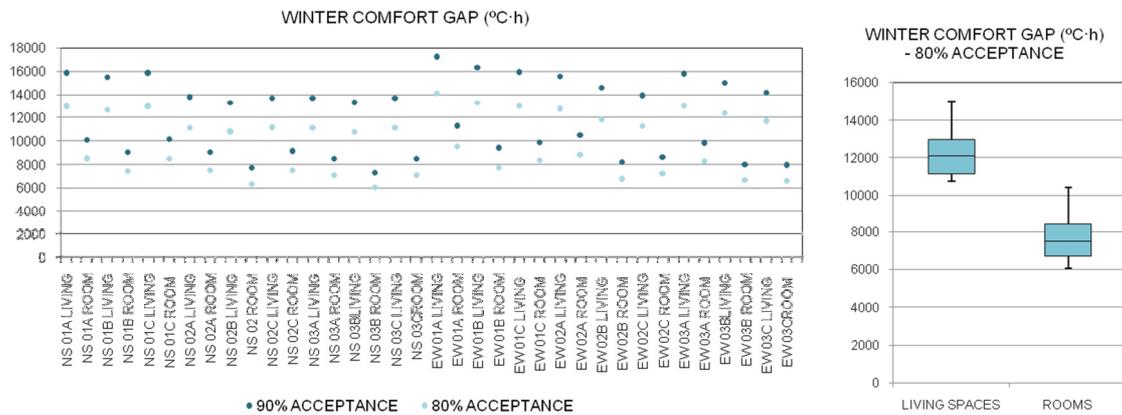


Figure 6 Left: Winter comfort gap in studied dwellings according to degree day criteria (°C-h). Right: Winter comfort gap ranges for all analysed living spaces and rooms.

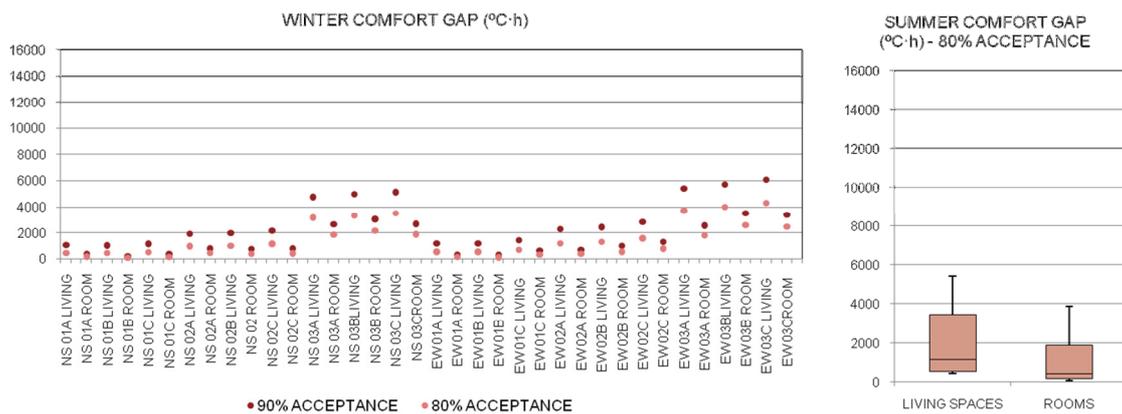


Figure 7 Left: Summer comfort gap in studied dwellings according to degree day criteria (°C-h). Right: Summer comfort gap ranges for all analysed living spaces and rooms.

As it can be regarded in figure 6, dwellings with worse winter thermal performance are those located in ground and upper floors and in the edges of blocks due to a larger exposed surface. The position within the urban morphology poses a weaker position regarding winter temperatures with a higher comfort gap in dwellings with east-west facades. Regarding summer temperatures, an east-west orientation and a border location within the block poses a worse summer performance in dwellings. By contrast, while upper floors suffer from the highest temperatures, ground floors enjoy the lowest summer comfort gaps as it can be derived from figure 7. Furthermore, figure 6 and 7 show that living spaces are those that registered highest comfort gaps, which can be explained due to longer occupancy hours. Nevertheless it must be highlighted a non negligible difference in thermal performance among different dwellings. These results go in line with previous research (13) which demonstrated the influence that the urban position of dwellings have upon their energy performance.



Conclusions

The *comfort gap* is found to be a useful tool in order to measure whether householders may be living under inadequate temperatures as well as the distance of these temperatures from comfort. Thus, this method allows the identification of those households more in need. Finally, given the studied case it can be stated that the poor thermal performance of these kind of constructions do not allow householders to live under adequate temperatures and that they can be considered as cold homes with summer overheating problems which reinforce the initial idea of the urgent inclusion of cooling needs in Spanish definition for fuel poverty.

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PM2.5 emission of urban dwellings in China: Case study from Fuzhou

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Abstract: *This paper aims to estimate smog (PM2.5) emission of urban dwellings in China, as part of a sustainability assessment of the building sector. It firstly estimates the life cycle PM2.5 emission of one dwelling project. Then the results are extrapolated to the whole urban dwelling stock to explore the responsibility of urban dwelling to the sustainable development in China.*

This Life Cycle Assessment study follows the ISO 14040/44 methodology based on the onsite data collection. The results indicate that 1) the operation stage is found to contribute the most to PM2.5 emission of urban dwellings. 2) The consumption of electricity constitutes the main elements causing this emission. 3) The construction of new dwellings and occupation of the existing dwelling stock in China annually cause approx. 1 million tonnes PM2.5 eq pollution.

Keywords, Dwelling, PM2.5 emission, urban, sustainable, China

1. Introduction

Smog, which is mainly caused by small particulate matter (PM2.5), is new and large environmental challenge for China. In 2013, Smog covers the middle and east china in average 30 days. Such air pollutions bring big health problem to Chinese residents. Buildings construction, coal combustion and transportation are estimated as three main resources of PM2.5 emission in urban China [1]. The Government released the plan to deal with such pollutants in 2013. However, there are few detailed actions to such pollutions, because the detailed information of contributors of PM2.5 is unclear. Especially, until now, there is little documented knowledge of PM2.5 emission from construction sector in China.

In past two decades, Chinese cities have become large buildings construction sites, owing to the urbanization and economic growth. At the first three years of this decade, around 0.7 billion m² new dwelling in urban are completed annually. These construction activities produce large air pollution to Chinese cities. Moreover, occupants of dwellings consume unrenowable energy, which is also one of main producer of PM2.5. Obviously, dwellings impact the environment during its service time, including construction, operation and

demolition. There are a number of studies analyses the environmental impacts of dwelling with life cycle perspectives [2-4]. Because of the requirement of national greenhouse gases reduction goal in many developed countries, greenhouse gases have higher priority in the context of sustainable building. The literature studies reveal that there are few studies with highlight PM2.5 emission from dwellings. Given the nowadays challenge of air pollution, the importance of PM2.5 emission for buildings in China cannot be ignored. This study tries to add the knowledge of PM2.5 emission casued by the dwellings's production and operation, especially those in China. Consequently, this paper aims to answer these two research questions:

- 1) What is the level of PM2.5 produced by per m² dwelling in China?
- 2) What are the hot spots and improvement opportunities of Chinese dwellings?

Using life cycle assessment, this study first estimates PM2.5 emission from a chain house construction project in Fuzhou. Second, this study estimates the PM2.5 emission of the whole dwelling stock in China.

2. Method and data

This life cycle assessment (LCA) study follows the ISO 14040/44 methodology [5, 6]. The LCA modelling has been carried out in Simpro V7.3.3 and excel file. The IMPACT 2002+ V2.11 method has been used to estimate PM2.5 emission. Data are mostly the field data, complemented with literature data when site-specific data were missing.

2.1 Goal and scope of the study

The goal of this LCA study is to estimate the life cycle of PM2.5 emission of a dwelling project in the southeast China. These results are then used to estimate the overall impacts from the existing dwelling sector in China in order to identifying the hot spots and improvement opportunities along the supply chain. The functional unit is defined as “the construction, occupation and demolition of one m² dwelling over its lifetime”. The lifetime of a building is a difficult parameter to standardise because it depends on many factors. This study assume the lifetime as 50 years [7-9]. The life cycle of chain house comprises three main stages: construction, operation and demolition. Therefore, the total PM2.5 is calculated as Eq.1.

$$E_t = E_c + E_o + E_d \quad (1)$$

Where E_t is total PM2.5 emission (kg) over the whole life time of dwelling; E_c are the PM2.5 emission (kg) during the construction stage of dwelling; E_o are the PM2.5 emission (kg) during the operation stage of dwelling; and E_d are tthe PM2.5 emission (kg) during the demolition stage of dwelling.

The construction stage involves the extraction and manufacture of construction materials and fuels, transportation through the supply chain and on-site construction activities of the



buildings. The use stage includes energy and water consumed by occupants for space heating, cooking, lighting, washing, appliances and so on. Due to the data access, demolition will not include the waste treatment.

2.2 System description, assumptions and data

The following provide an overview of system boundary, the assumptions made for and the data estimation. Table 1 summarise the main consumption information considered in this study.

Table.1 shows the data of all consumption of material and energy for construction. This data is taken from the tender and on-site report. The construction materials are assumed to be transported 50 km from the manufacturing gate to the construction site and all transport is assumed to be by road using 8 t capacity trucks. Machines and tools for tunnel construction are used for more than one construction site. Due to the lack of data concerning the reuse of machines, this study does not take the consumption of machines and tools into account. It also excludes the transportation of construction machines, equipment and tools to the site. It, however, calculates the energy consumption for equipment operation and transport on construction site.

The assessment of waste disposal during the construction stage and demolition stage includes only the handling of excavated soil. The excavated soil was reuse onsite as much as possible. The rest of excavated soil and other waste are assumed to be transport 100 km away from dwelling site. Since there is few data on construction waste disposal in china, this study exclude the treatment of these waste.

Doors, windows, equipment and inside decorations are different from project to project during the dwelling occupied. Consequently, the assessment of operation stage does not include this consumption. Equally, the consumption in the operation stage only considers the energy and water used by occupants. Residents in the urban of Southeast China mainly use electricity and nature gas for their daily life. Total energy and water use in the 50 years of operating of per m² is estimated in Table 1, according to the data base of statistics for domestic energy use at Statistics Fujian. The data of dwelling stock, used in this study are based on statistical data published by Statistics Fujian and Statistics China.

Table 1: Material and energy consumption of per m² dwellings

Stage	material/energy	unit	amount
Construction	brick	kg	36,59
	autoclaved aerated concrete block	kg	60,98
	steel	kg	49,61
	concrete	m ³	0,48
	mortar	kg	67,72
	bitumen seal	kg	0,89
	tile	kg	10,32
	XPS	kg	0,26

	door outside	m ²	0,01
	flat glass	kg	2,62
	window	m ²	0,19
	diesel	kg	0,18
	electricity	kwh	10,58
	water	kg	11,23
Operation	electricity	kwh	1618,71
	water	ton	71,94
	gas	MJ	1541,01
Demolition	diesel	kg	0,26

The background life cycle inventory (LCI) data have been sourced from the Simpro V7.3.3 various databases. Where China-specific LCI data have not been available, the data used from the databases have been adapted as far as possible to reflect the China conditions, particularly with respect to the Chinese electricity.

3. Results

Fig.1 illustrates the relative contribution of each stage to total PM2.5 emission. Fig.2 explains the relative contribution of the process to the construction stage. Equally, Fig.3 demonstrates the relative contribution of each input to the material consumption.

The operation stage is the dominate contributor to the PM2.5 emission (80%), mainly owing to consumption of electricity. The use of electricity causes 96% of PM2.5 emission at the operation stage. The construction stage contributes with 18% of the total PM2.5 emission, because of the consumption of steel, concrete, tile and transportation. Steel and concrete is responsible for 27% and 25% PM2.5 emission at the construction stage, respectively. The dust caused by the construction and demolition activities is clear visible, although the contribution of on-site construction work and demolition only contribute less than 1% to the total PM2.5 emission.

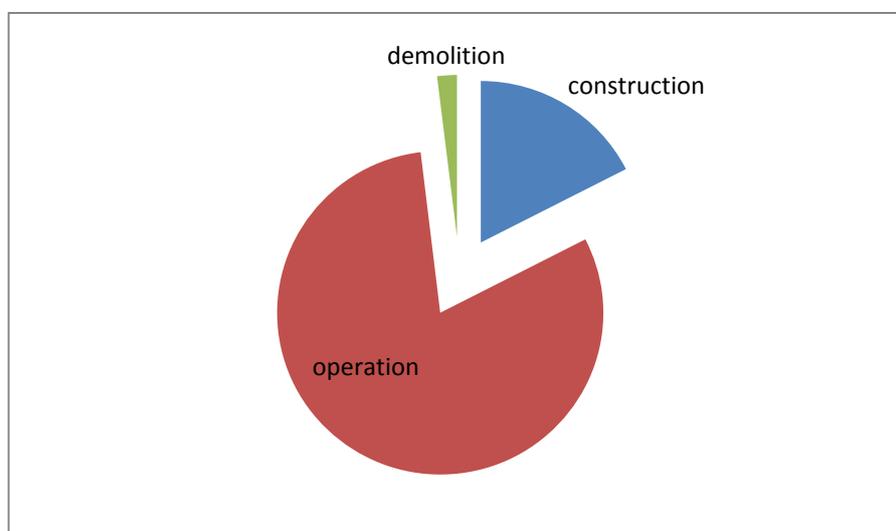


Fig.1 Relative contribution of each stage to total PM2.5 emission

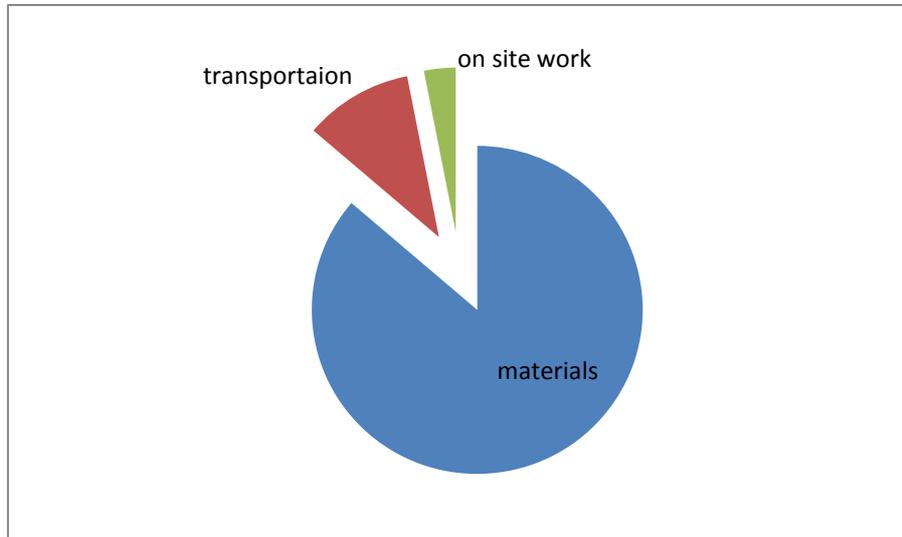


Fig.2 Relative contribution of processes to PM2.5 emission at construction stage

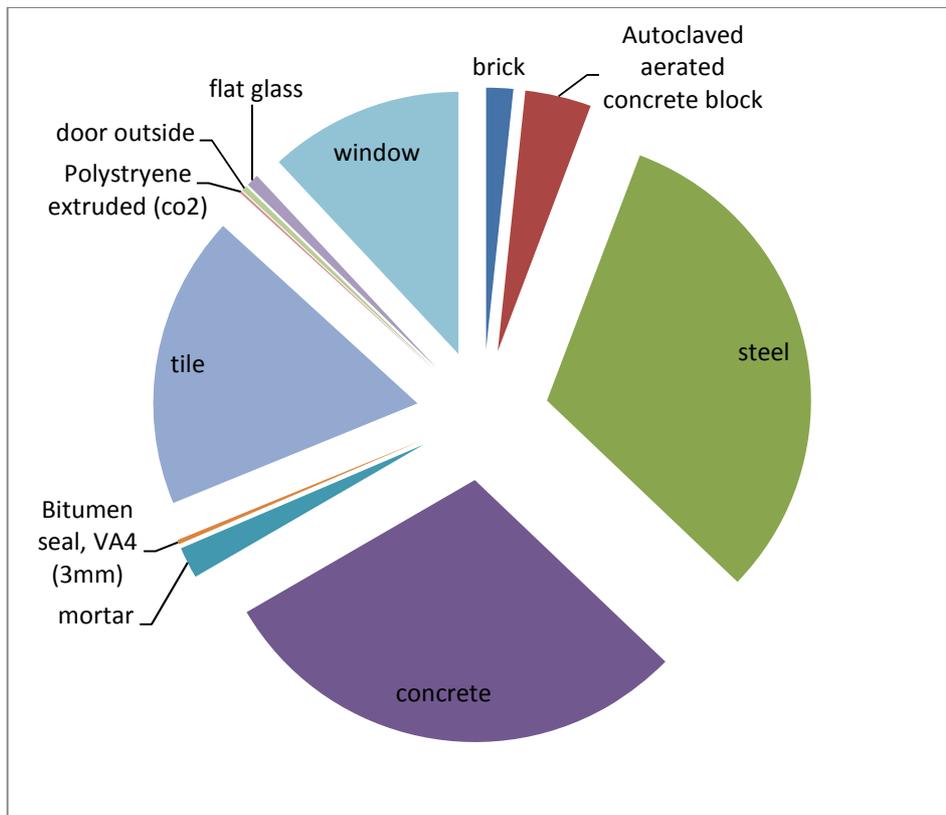


Fig.3 Relative contribution of inputs to PM2.5 emission at the material consumption

According to the Chinese climate classification for buildings, Fuzhou is located at the climate zone of hot summer and warm winter. There are five different climate zones in China. As



results, the residential energy consumption in this case study will be different from other city. Therefore, the average residential energy consumption can be used to estimate the PM_{2.5} emission of the operation of the existing dwelling stock in China. Moreover, all new dwellings are built with concrete and steel. Even there is different type of dwellings; the consumption of materials per m² for framework construction is similar. The PM_{2.5} at the construction stage can be used to estimate the PM_{2.5} emissions of the whole building constructions in China. In 2012, the new dwellings completed in China is 0.79 billion m² [11]. Consequently, there are around 0.6 million tonnes PM_{2.5} caused by residential energy use and 0.5 million tonnes PM_{2.5} emitted from the construction of new buildings in 2012.

4. Discussion

According to the results of the analysis, it is found that material consumption, material transportation and electricity consumption entail rather significant PM_{2.5} emission in China. Equally, electricity, steel, and concrete are the three main contributors to the PM_{2.5} emission caused by dwellings over their life cycle.

Consumption of electricity causes 78% of total PM_{2.5} emission over the dwelling life time, mainly because of spacing cooling/heating, lighting and washing at operation stage. This consumption at operation stage is site-specific, being influenced by a number of factors, such as household size, income, occupants' behaviour, efficiency of appliance, etc. To reduce the use of electricity, policies can include encouraging occupants to saving energy and industry to building more low energy dwellings.

Steel and concrete are the two main materials causing the PM_{2.5} emission over the dwelling life time. Thus, one potential approach to reduce the PM_{2.5} emission seems to be reducing of the steel and concrete consumption for dwellings, and producing materials with lower emission intensity. Seeking an environmental friendly up-stream supply chain of material, however, cannot ignore the role of electricity for manufacture.

The environmental impacts resulting from electricity consumption do only rely on the amount of consumption but also on the electricity production mix. Around two thirds of electricity in China is produced by coal [10]. Such coal dependent electricity is the main source of Chinese air pollution. Therefore, the increase of the blend of cleaner electricity would be another policy choice.

5. Conclusions

Using dwelling project tenders completed in Fuzhou at 2013, this study has firstly explored the PM_{2.5} emission of a chain house project, and secondly accounted the PM_{2.5} eq emission of whole dwelling sector in China. It reveals that:



- 1) One m² Chinese dwelling emits at least 3.7 kg PM_{2.5} eq during its 50 years life span. Such emission mainly stem from the consumption of electricity. The operation stage has major responsibility to such emission.
- 2) Electricity, steel, and concrete are the three main contributors for PM_{2.5} emission. Therefore, improving the energy efficiency of buildings and appliance, and optimizing framework design to reduce the amount of such main consumptions would play key role in reducing the environmental burden of Chinese dwellings. Moreover, policies promoting more renewable energy production and consumption constitute another import issue for environmental friendly dwelling.
- 3) There is around 1 million tonnes PM_{2.5} eq emission caused by the construction of new dwellings and occupation of the dwelling stock in 2012. Such air pollution cannot be ignored in the sustainability assessment of dwellings in China.

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Psychotherapeutic and Team Building Initiative of Greening Construction Sites – The Case Study of an ‘Oasis in the Desert’

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Abstract: *The temporary nature of the contract, uncertainties and the inherent danger involved in construction work, extremities of temperatures, and the lack of natural synthesis and the symbiotic support of natural ecosystem or healing contact with nature, are psychotraumatic factors on construction sites. These issues exacerbate the stress of the constant threat that fatalities and injuries have on the health, well-being and performance of workers. The psychosocial stress inherent in these factors in turn presents an unavoidable challenge to effective communication and beneficial interaction among construction workers that could compromise health and safety (H&S) issues. A therapeutic and beneficent biophilic workplace environment could be a necessary catharsis for sustainable and spontaneous interaction that could spur community and team building initiatives with a significant impact on improved performance and productivity of workers on the project.*

The case study of a psychotherapeutic garden design on a construction site in the Northern Cape Province of South Africa exemplifies these findings. An exploratory field survey conducted on the site includes a focus group study of both workers and management regarding the ‘green’ initiative on the construction site aptly dubbed ‘an oasis in the desert’. Deductions from the findings indicate that the originality of the innovative strategy of a biophilic workplace design adds value to ergonomics for human factors and sustainable sites initiative in construction and enhances communication, interpersonal relationship, and team building initiatives.

Biophilic design, communication, construction performance, team building, health and well-being.

Introduction

Literature exposes the construction workplace as an environment in dire need of the psychotherapeutic intervention of a biophilic design concept [15]. The range of psychosocial risk factors involved in construction work begins with the disregard of the psychosocial value and natural aspects of the workplace environment [16]. The blatant disregard for the aesthetics and social benefit of human interaction with nature on construction sites could have untold emotional impact on the health, wellbeing and performance of workers [6, 11]. The inherent danger and demand of construction work could be likened to the stress of hospital and health facilities with the constant background threat of fatal consequences that could be a constant source of irritability and nervous reactions [2]. The mood thus generated could be dampening on the ability of employees to communicate effectively, interact and socialise with one another [8, 14]. By implication, communication becomes a severe challenge that could compromise mutual trust and understanding among workers [1, 9]. According to research



findings the hospital and health facilities have long since adopted the biophilic design concept of incorporating therapeutic garden designs in various forms within and around its facilities with proven benefit overtime [2]. The question is: could therapeutic garden design have the same sustainable impact on construction sites? If so, how could it be effectively implemented and sustained?

The objective of the study is to determine the impact of a green construction site on the health, wellbeing communication and team building initiative of employees in construction. The objective envisions a construction workplace environment that is healthy and spiritually conducive to effective communication, beneficial interpersonal relationships, community, and team building initiatives which could be of mutual benefit to H&S, performance, and well-being issues in construction. It represents an effort that employs the proven benefit of the Biophilic Construction Site Model (BCSM) [12, 13]. The methodology involves a survey of an existing construction site in the Northern Cape Region of South Africa that includes a focus group study of both management and workers. It involves an exploratory study of the innovative H&S strategy of ‘greening construction sites’ that is spontaneously implemented in the construction workplace as a form of psychotherapeutic measure by the H&S management team. Findings expose the beneficial and interactive nature of a communicative and aesthetic biophilic construction workplace environment derived from nature towards enhanced health, performance and wellbeing of all stakeholders in construction. The BCSM is hereby considered a silent team mate that binds, sustains and supports communication, relationship building blocks and the H&S strategy in construction. This research therefore proposes the procurement and provision for the BCSM in construction workplace designs and tender bids as a cost effective team building initiative and environmental sustenance factor in construction projects.

The BCSM, Green Performance indicator, Communication, wellbeing and worker performance

The BCSM is a spatial and psychosocial ‘green performance’ index that involves the greening of construction sites [1, 12, 13]. It is a derivative of biophilic workplace design, which is a factor that derives its substance from the theory of biophilia [7]. Biophilia is a theory that authenticates the symbiosis of ecosystem support and emotional sensitivities that address the innate natural affiliation of humankind to nature and all living organisms [18]. Kellert & Wilson [7] have developed the biophilia hypothesis in collaboration with findings from a number of researchers across the professions that validate the health, safety, performance, and wellbeing benefits of a restorative natural environment or biophilic environment [4, 13]. The significance of these findings have shown the necessity of developing a biomimetic interaction with nature in all aspects of human endeavour that could yield a wholesome and all inclusive health, well-being and performance of all stakeholders involved [2].

A range of research findings indicate that the restful, aesthetic psychotherapeutic benefits so derived could lead to spontaneous communication and interaction, that would yield mutual trust, fraternity and team work among the workers [16]. Through this effort, a life sustaining



environment with increased access to open spaces, improved air quality, reduction in the urban heat island (UHI), as well as reduction of waste and increased biodiversity is developed and sustained in keeping with ergonomics [10]. Research findings indicate that these interpersonal relationships cannot exist outside of the participants involved, and most importantly, are created, maintained and altered through communication [14].

The WHO [17] defines team building as two or more people working interdependently towards a common goal. The objective could serve as a ‘green performance indicator’ if given a ‘green’ incentive as its norm and formative core [1]. Various research findings [8, 9] have shown that the goals of a team could be developed through a group process of team interaction and agreement that enables and encourages team members to bond and work effectively in-order to achieve a common objective such as the BCSM. A durable social network and mutually gratifying relationship enriches lives by offering valuable support [14]. In a social environment where compassion and assistance is accepted and offered, individuals experience a sense of belonging and stability [14].

Wessel’s mine case study – ‘Murray and Roberts Cementation Construction Site’

The research methodology involves a case study and survey of an existing construction site in the Northern Cape Region of South Africa. The applied technique used for data collection and analysis of the case study involved the focus group study of workers and management which included interviews, photographs, and personal observations. The survey was part of a larger study conducted during the hot arid summer season of the Northern Cape region.

Description and Background of Study

By virtue of its climatic condition and geographical location the construction site is known to be very hot in summer, and extremely cold in winter. Geologically it is very arid and of a semi-desert nature, with more than 21km of sand atop a dense manganese core according to a BHP Billiton Geological Survey Report for 2013. Wessel’s mine is located at a lonely place in Hotazel (Hot as hell) near the Kalahari Desert about 86km and one hour’s drive from the nearest town, Kuruman. The ‘rose garden courtyard with water fountain’ concept was developed as part of the Health, Safety and Environment performance enhancing programme for the M&R staff consisting of both management and workers of diverse construction trades.

Description of Study population and Respondents

The four construction companies involved in the Central Block Project as shown in Table 1 include: M&R Cementation as the main contractor directly involved in the construction of the ventilation shafts and who share the same construction site office premises (CS-1) with the Synntech Project Management (PM) team; Bashewa Construction contracted to build the new ventilation fan substation and Motor Control Centre (MCC) Building that will energise the three ventilation fans for the shaft and share site office premises (CS-2) with Olivier construction involved in the civil works construction. The sample population for CS-1 is 119 and 28 for CS-2.

Table 1. Details of employees and respondents from each company

Const Site	Const. Company	Project	No of Staff	Staff surveyed	Respondents
CS-1	M&R Cementation	Vent Shaft	204	109	33
	Synntech PM	Project Management	10	10	10
	Total		214	119	43
CS-2	Bashewa	Electrical.Substation	10	10	10
	Olivier	Civil Works	40	18	15
	Total		50	28	25

(Source: Obiozo and Smallwood, 2013)

The representation of the target respondents cut across various trades in the construction industry including the management and administrative staff. CS-2 and CS-1 are interlinked. CS-1 is located closer to the entrance to the Wessel’s mine Central Block Premises such that the staff and management with office premises located at CS-2 have to pass through CS-1 to get to the offices and project site. CS-2 is located next to the project site such that the staff and management with office premises located at CS-1 have to pass by CS-2 to get to the project site or Vent-shaft.

Single Element Study: The Rose Garden Courtyard with the Giant Water Jug Fountain – An ‘Oasis in the Desert’

M&R Cementation established a green construction site which includes a ‘rose garden courtyard with a water fountain in a giant concrete pot’ as its focal point and foundation stone of their Wessel’s Mine Construction Site in the latter half of 2008 (Photos 1, 2, 3, and 4). A greening construction site survey was conducted at CS-1 involving a single biophilic element study of the ‘rose garden courtyard with water jug fountain’ fondly dubbed ‘an oasis in the desert’ (Photos 1 and 2).



Photos 1, 2, 3, and 4. Rose garden courtyard in its early stages in 2008; its full grown stage in 2013; site entrance location adjacent to the rose garden; view of the construction site through the rose garden courtyard within the site office premises; source: field survey.



Photos 5, 6, 7 and 8. The giant water jug fountain in the courtyard before the trees and rose garden were planted in 2008; the nature devoid construction site; the tree planting exercise as an all staff initiative; the green grass verge in the workers’ changing room courtyard extension (courtesy of M&R Cementation).

Key Biophilic Design Features – Nature based concept of the BCSM

Four cardinal trees of the Hydrangea Macrophyllia specie were originally established as cardinal points in the rose garden courtyard for organisational effectiveness, namely, Tree of



Endurance, Tree of Loyalty, Tree of Respect and Tree of Just (Photos 1 and 2). Other trees were subsequently planted at various locations around the courtyard with the original four as focal points on the right side of the entrance to the construction site (Photo 3). The gigantic water jug fountain (Photos 1, 2 and 4), was located in the middle of the courtyard with rose bushes surrounding it signifying life and growth according to research findings [6, 7]. As well as being a water feature, it also represents a life like sculpture made out of clay which is of earth material and appeals to the sense of life, order and harmony with nature in accordance with the eco-psychology study [3], nature-psychophysiological study [11], and restorative environment study [2]. An additional water feature is the water vent located around the garden on the eaves of the roofs of the surrounding site office containers, which not only constantly sprays the garden with water, but also humidifies the air. The M&R construction site was initially devoid of natural vegetation and plants (Photos 5 and 6).

Results and Analysis of the findings

The deductions from observations and interviews with management and workers include the following:

1. *Community building and team spirit:* The planting of the garden was a collective effort of both management and workers from the highest to the lowest cadre across the staff hierarchy as shown in Photo 7. The M&R construction management team admitted that as a result of many years of experience it has identified this all-inclusive strategy as a means of positively impacting the organisation effectively each time. This signifies the need for staff involvement in-order to achieve a holistic and personalised result [1];
2. *Evidence of Wellbeing and psychotherapeutic benefits:* According to the team; the rose garden courtyard serves as an ‘oasis in the desert’ to enhance the psychosocial value of the construction site, health, wellbeing and performance of all staff. In both design and concept it has significantly created a pleasant environment with a beneficial micro climate within the construction site offices; providing fresh, clean, oxygenated and moist air, which keeps the staff active, attentive, relaxed and upbeat or in high spirits constantly, as their various duties constantly take them round and about the courtyard or garden;
3. *Personalisation and psychosocial benefit:* The rose garden courtyard has become an aspect of personalisation as each member of staff identifies with it in their own personal way as an ‘icon of life’ at the site. This view was expressed by the H&S management and supported by both workers and management during the focus group interviews. It is considered an enduring source of sustenance during the day, and a succour and healing presence at the end of a stressful work day;
4. *Social interaction and team building initiative:* The presence of the garden has helped to relieve stress, fatigue, and boredom among the staff. The H&S manager further stated that the presence of the rose garden courtyard has, by a large margin, enhanced the social network and team building initiatives of the organization. A testimony to this fact is that the focus group interview and interaction with the workers was



conducted within the courtyard by their own suggestion not at the conference room as was originally planned;

5. *Nature-psychophysiology and improved communication:* The rose garden courtyard provides a cool restful environment for spontaneous dialogue, informal meetings and interaction among the staff. The H&S team of M&R Cementation concurred and noted that this situation of communion and interaction among the staff would not have been possible in a physically repulsive environment devoid of nature. The lack of a beneficent view and environment would have naturally kept most people within the confines of the offices most of the time to avoid the stark, arid, and uninviting reality of such a workplace environment;
6. *Attachment to the organization:* A visible sense of attachment to the organisation, to one another and the worksite environment clearly exists among the employees. It is notable that a particular group of workers whose offices were located in the new construction site extension began to voluntarily green their portion of the site, according to M&R's H&S management report and interview with the workers (Photo 8). Grass sods from the other green areas were planted on the bare patch of their own section of the construction site by them, until fully covered with green grass, and
7. *Green performance index:* The sense of appreciation and commitment to management's 'green' effort is of such value that their portion of the site has remained green even with the prevailing reticulation problem on the construction site. It represents a unanimous and collective factor of team work because the workers have maintained the grass in that area 'green' with waste water from their changing room all through the harsh arid summer season of the hot dry climate of its location.

Discussion from Research Findings and link with existing literature

Research indicates that shared values, concepts, attitude, and healthy and safe behaviour on the part of workers contribute to H&S culture [1, 8, 9]. Workers' perspectives regarding H&S, well-being, and performance are interdependent and not isolated [1, 8, 9] and are intrinsically related to an organisational structure that fosters shared concepts among workers in an environment imbued with physical and cognitive wellbeing [16]. Goodwill built on interpersonal trust is an attitude that is encouraged within a pleasant and psychotherapeutic communal environment where emotional support is offered in the form of the BCSM [14]. Findings indicate that the BCSM draws on nature's principles to build an empathetic, understanding and love filled environment by employing the biophilic amenity of emotional human cognitive affiliation to nature [18, 2, 14, 1, 13, 15].

Conclusions and Further Research

From the focus group study it is clear that the rose garden courtyard is clearly regarded and viewed as an aspect of health and wellbeing among the staff by both workers and management. It has also encouraged communication and interaction among employees, building fraternal spirit that is beneficial to the organisation's H&S initiative. The effect has been rejuvenating and therapeutic in relieving psychosocial stress among the workers. The BCSM is therefore recommended as a community and team building initiative on construction



sites in furtherance of psychotherapeutic H&S culture and wellbeing. In furtherance of positive research in construction, organisations should employ the BCSM as an H&S team building block and enabling environment that becomes a silent partner in which to share common values of benefit to individual workers and the organisation [17, 9, 1, 14, 8].

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ANNEX

PEER REVIEWED SESSIONS – “TRANSFORMING REALITY”



Session 75:

Are current building regulations adequately advancing sustainable buildings? If not, what is missing, and how should they be changed? (I)

Chairperson:

Serra, Javier

Ministry of Infrastructure, Spain



Are current building regulations adequately advancing sustainable buildings? If not, what is missing, and how should they be changed? (Part I)

Chairman: Serra, Javier, Ministry of Infrastructure, Spain

Speakers:

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Abstract: *This session brings together policy-makers, government officials, researchers and others to present perspectives on how innovation in building regulation and control, such as performance-based approaches, are currently being used to advance sustainability concepts in buildings, whether we are doing enough, and where and how we might see further innovation in the coming years. In this grouping of session papers, representatives of the Inter-jurisdictional Regulatory Collaboration Committee (IRCC) and the International Council for Research and Innovation in Building and Construction (CIB) Task Group 79 discuss a range of policies implemented in their countries and/or the focus of research and development in their respective countries. Related papers can be found in the corresponding set of session papers (Are current building regulations adequately advancing sustainable buildings? If not, what is missing, and how should they be changed? (Part I)).*

Keywords: *building regulatory systems, building control, performance-based, sustainability, climate change, resiliency*



Resilience of Australian Buildings to Extreme Weather Events

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Matthew MCDONALD, Group Manager, Strategic Policy, Australian Building Codes Board, Canberra, ACT, Australia (Matthew.McDonald@abc.gov.au) – *Resilience of Australian Buildings to Extreme Weather Events*

Abstract: *The policy direction for the work the Australian Building Codes Board (ABCB) undertakes in the area of sustainability is usually derived from Government. These directions place policy expectations and boundaries upon the ABCB that impact on the way it is able to deal with the challenges relating to sustainability. The ABCB has traditionally dealt with some elements of sustainability, such as resilience to extreme weather events, under the building code core objectives of health, safety and amenity. Additional elements, such as energy efficiency, have been added over time which has resulted in the addition of sustainability to the core objectives of the code but not all risks and similarly not all buildings are addressed. The vast majority of existing buildings were constructed before the current sustainability requirements came into force. This means that many occupants of existing buildings are vulnerable to higher relative risk.*

Key words: *Australia, sustainability, climate change, natural hazards, resilience, regulation, building.*

Background

Effective resilience to extreme weather events (or extreme climate related natural hazards) involves a number of strategies across all levels of government, business and communities. These strategies include consideration of settlements and infrastructure, emergency planning and response, insurance, and human health. For the purpose of this paper, consideration is limited to buildings, structures, and plumbing systems, which come under the domain of the Australian Building Codes Board (ABCB) and the National Construction Code (NCC).

To provide an understanding of what 'resilience' means for the purpose of this paper, the following definition contained in the Intergovernmental Panel on Climate Change (IPCC) 2012 report *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* is useful.

“Resilience: The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions.”

Not to be confused with property protection as an outright objective, a critical future challenge facing the ABCB is ensuring that the NCC contains appropriate standards for buildings and plumbing systems to be sufficiently resilient in the face of natural hazards affected by extreme weather events, which may change over time. This is not, however, a new concept for the ABCB.



The ABCB's mission, references sustainability in the design, construction and performance of buildings. In turn this is reflected in the NCC requirements for new buildings and plumbing systems to be designed and constructed to withstand extreme climate related natural hazard events, including wind and cyclones, rainfall, snow, bushfire and flood, as appropriate to their location.

The ABCB has traditionally relied on historic climate and weather data when setting standards for the resilience of buildings, structures and plumbing systems facing extreme natural hazards and extreme weather events. In addition, the ABCB has promptly investigated natural disasters to determine whether the current NCC provisions are appropriate and has developed new provisions where required.

Changes to the NCC are subject to compliance with Council of Australian Government (COAG) best practice regulatory principles; this includes a cost benefit analysis, regulation impact assessment (RIS) and consideration of available data and research. However, more recently the ABCB has sought to utilise scientifically based climate projections such as in its review of wind standards for construction in cyclone affected areas.

There are a number of policy expectations and boundaries placed upon the ABCB that impact on the way the ABCB is able to deal with future challenges concerning extreme weather events. At a national level these include, the policies of different governments, societal expectations, cost benefit analysis and the availability of data.

One of the main objectives of the ABCB is to ensure that the NCC requirements are as far as practicable nationally consistent. This does not mean, however, that 'one size fits all' because different locations can have geographic, climatic or other differences, but the overall risk levels to the community should be reasonably similar.

Governments require the ABCB to undertake a regulation impact analysis for every significant change to the NCC, which includes an assessment of net benefits and costs, and justification for the most appropriate option. The analysis must be cleared by the Government's Office of Best Practice Regulation, which also determines the applicable discount rate. The analysis ultimately informs the decision making process of the Board but it is not the only consideration and the Board has the ability to choose an option that may not provide a clear net cost saving to the community but delivers life safety.

Climate related natural hazards currently addressed by NCC

Buildings are currently designed and constructed in accordance with the NCC to withstand climate related hazards such as cyclones and extreme winds, intense rain, bushfire, snow and flood, as appropriate to their location.

These hazards impose loads and risks to buildings determined mainly by historic records and post event analysis, from which design events with annual probabilities of exceedance are specified.

Building standards have undergone constant review, particularly after major hazard events and via research, to ensure adequate levels of safety and health are maintained for the community. Where the building standards proved to be inadequate, as identified in the wake of Cyclone Althea in 1971 and Cyclone Tracy in 1974, they were subsequently upgraded (refer Figure 1 for example of damage caused by Cyclone Tracy impacting on Darwin).



Figure 1: Example of damage - Cyclone Tracy

These improved standards for high wind design were later demonstrated to be satisfactory as evidenced by the small number of building failures resulting from Cyclones Vance, which affected northern WA in 1999, and Cyclones Larry and Yasi which affected northern Qld in 2006 and 2011 respectively. However, the largest problem identified by recent cyclone investigations relates to pre-1980 buildings that were designed in the main to lesser standards and which have often been weakened by material degradation and inadequate maintenance (refer Figure 2 for example of damage to older housing caused by Cyclone Yasi).



Figure 2: Example of damage to older house - Cyclone Yasi

The ABCB has undertaken a recent study into the impact of climate change on the NCC. The Report found that by and large, buildings designed and constructed in accordance with the current NCC are likely to be reasonably adequate for climate related hazards anticipated in 50 years- time, associated with a low emissions scenario. If the climate changes in accordance



with high emissions scenarios however, the current BCA is likely to be deficient in some areas.

Whatever the emission scenario, potential climate change impacts at both a regional and national level require constant monitoring and review to ensure the NCC's established level of safety is proportional to the likely hazard intensity and resultant risk of damage.

The fact the NCC currently addresses a number of natural hazards through what have been adjudged to be proportional minimum performance requirements, results in both significant social and financial benefits for the Australian economy.

For example, a report by Risk Frontiers, Macquarie University in December 2007 for the ABCB entitled 'Financial benefits arising from improved wind loading construction standards in Tropical-Cyclone prone areas of Australia', found that '...the improved building standards have been enormously successful with our calculations suggesting that they have been responsible for reducing annual average cyclone-related losses by nearly two thirds'. The report estimates that this equates to a present value benefit of future loss reductions equalling AUD14.2 billion. It is anticipated that additional significant financial benefits will also accumulate from the other natural hazards addressed by the NCC.

The impact of climate changes on wind and cyclones appears minimal at this stage. An investigation commissioned by the ABCB reviewed recent studies of climate change effects on tropical cyclones. The studies indicate that in the Australian region, the total number of cyclones has diminished. However, there is evidence that the number of more severe events has increased. Simulations of future climate, with projected increases in CO₂ concentrations, also predict fewer cyclones, but further increases in more severe tropical cyclones. One of the more significant scenarios is the possibility of a greater risk of a severe cyclone affecting South-East Queensland.

Hazards not addressed by NCC

The NCC currently does not cover hail, storm tide or have specific requirements relating to heat stress. However, for heat stress, the NCC energy efficiency requirements would moderate the impacts of extreme heat within buildings that have been built to contemporary energy efficiency standards, resulting in reduced risk of heat stress for building occupants.

Some of the largest insurance property losses result from hail damage (e.g. the 1999 Sydney hailstorm). However, any proposed changes would need to pass regulation impact analysis. It is unlikely it would be cost effective to require all external building materials to resist hail impact, taking into account the localised nature of such storms, the cost of upgrading or restricting certain building materials, and the low risk to life safety.

Storm tide is potentially a very high risk in low lying coastal communities, especially those subject to the risk of cyclones. However, it would be very costly and restrictive to design and construct buildings to resist storm surge because of the significant water forces involved.

Restricting development in high hazard areas via planning controls may provide a more realistic solution.

Recognising the inter-operability of building and planning controls for natural hazard mitigation is crucial, not only to ensure the correct geographic locations are identified for the application of building standards, but also because the best way to reduce risk to life and property is to determine where buildings should or shouldn't be built in the first place.

It is also important to note that the vast majority of buildings that are highly exposed to natural hazard events already exist. The NCC does not apply retrospectively unless required by State and Territory laws (such as in the case of swimming pool fences). This means it will take a long period of time for the existing stock to be replaced or incrementally improved as owners undertake renovations that require the building to meet the current requirements of the NCC.

Impact of climate changes on extreme weather events

The weight of scientific analysis tells us that our climate is changing and this may impact on extreme weather events such as storms, floods and heat waves. Data is also confirming that temperatures are rising and that the impact on rainfall appears more variable around the country (refer Figure 3 showing changes in average temperature for Australia from 1910-2010). However, the impact of these changes on extreme natural hazard events is not always apparent.

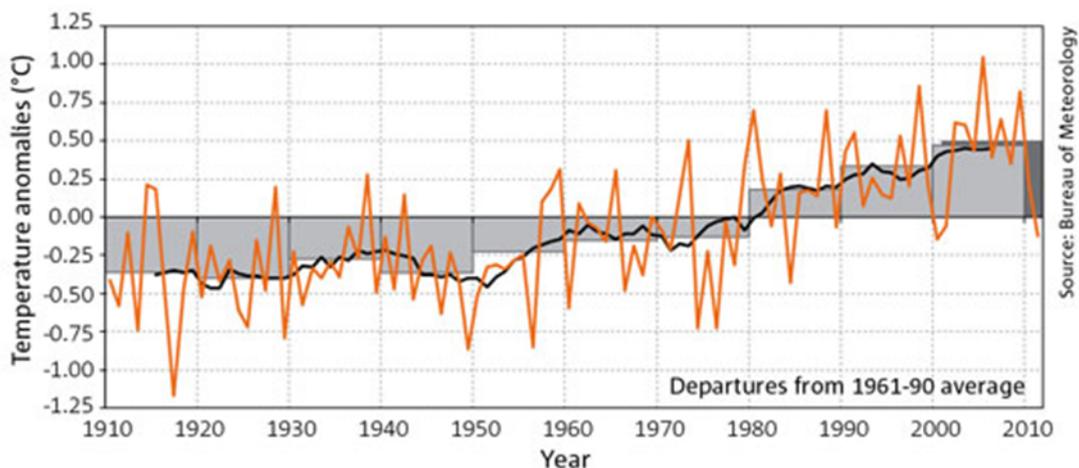


Figure 3: Changes in average temperature for Australia

In addition to the climate change implications for weather affected natural hazards impacting on buildings, other significant impacts on potential risk to life and building damage include the increasing density of settlements and the increasing dwelling size and value. In other words, a greater number of buildings of increasing value are being exposed to extreme weather events. Examples include increased density of settlements on the coastlines and river systems of Australia which are exposing a greater number of people and buildings to cyclones

and other extreme winds, flooding and storm surge (refer Figure 4 showing increase in development on the Gold Coast from 1950's to present).



Figure 4: Contrast of Main Beach, Gold Coast Queensland, in the 1950's and in more recent times (Source Gold Coast Tourism Bureau)

Even if the risk of extreme weather events does not increase, the greater density and value of settlements exposed to these risks will mean that losses of life and property will inevitably also increase.

Conclusion

The ABCB is committed to comprehensively reviewing and considering the impacts of extreme weather events in relation to all relevant new regulatory initiatives but the ABCB is not a climate expert. The ABCB must rely on climate/weather experts to provide advice, research and evidence to establish whether and to what extent climate changes are impacting on extreme natural hazards and should be taken into account in determining the coverage and appropriate risk levels in the NCC. This must occur in conjunction with policy makers having regard to the science and providing strategic direction for the ABCB in undertaking its work.

The ABCB has robust processes in place to ensure the NCC adequately addresses future extreme weather events, and that codes are continually refined and improved. All changes to the NCC must be evidence based with the problem clearly articulated and the response proportional to the issue being addressed.

The largest concern is in relation to existing buildings constructed prior to today's contemporary building standards. These buildings are likely to be vulnerable to current climate hazard events, so would be even more vulnerable when faced with the prospect of more severe future events.

The challenges will also stretch the capacity of the ABCB to maintain national consistency and minimum performance standards across jurisdictions for new building and plumbing work, whilst ensuring the NCC continues to meet its objectives of minimum performance standards for safety and health, amenity and sustainability.



Finally, the ABCB needs to continually engage with its stakeholders to ensure there are ample opportunities for input and to ensure that all potential impacts of proposed changes are fully identified and analysed before final decisions are made.



Life-time Environmental Sustainability of Buildings under the Singapore Building Control Act

Note: This paper has been peer reviewed by the World SB14 Barcelona Scientific Committee

Author:

Jeffery NENG KWEI SUNG, Centre for Sustainable Building and Construction, Research Group, Building and Construction Authority, Singapore (Jeffery_NENG@bca.gov.sg) – *Life-time Environmental Sustainability of Buildings under the Singapore Building Control Act*

Abstract: *With a land area of 723.2 km² housing a population of 5.4 million, Singapore is one of the most densely populated countries across the world. Given our scarce resources and limited land, it is imperative to ensure developments go hand-in-hand with efforts to preserve our environment in tandem with rapid urbanisation and increased population. As the authority for the building sector, Building & Construction Authority (BCA) plays a leading role in steering the building sector towards sustainable development. In 2005, BCA has spearheaded and launched the BCA Green Mark Scheme,¹ with the objective to promote the adoption of green building design and technologies that improve energy efficiency and reduce the impact of buildings on the environment. While there has been considerable headway in promoting the development of green and sustainable buildings in Singapore, there is a need to ensure that appropriate regulations are in place to provide the relevant impetus on the desired reduction in energy consumption and carbon emissions. The paper will discuss on the legislative frameworks in place under the Singapore Building Control Act and how these frameworks would help advance the sustainability concepts in buildings from design to operation.*

Keywords: *Sustainable Development, GreenMark Legislation, Building Control, New Buildings, Existing Buildings, Periodic Energy Audit, Energy Consumption Data*

Introduction

In Singapore, the building sector is the third largest contributor to Singapore's carbon emissions after the manufacturing and transport sectors, contributing 16% of the total carbon emission. To reduce carbon emission levels of buildings, there is a need to optimise the energy usage of buildings while minimising the use of carbon intensive materials and waste generation. In essence, buildings would have to be designed, constructed and maintained to be energy-efficient and environmental friendly, beyond merely fulfilling the functionality. To start with, the public sector being a large consumer of resources in building development and ownership, has initiated a range of measures to drive resource efficiency since 2006 under the Public Sector Taking the Lead in Environmental Sustainability (PSTLES) initiatives. Under this PSTLES framework, all public sector agencies are required to submit an annual

¹ The BCA Green Mark Scheme is a green building rating system to evaluate the environmental impact and performance of buildings launched in Jan 2005. Today, BCA's Green Mark scheme has become the national yardstick to rate the environmental performance of buildings and the qualifying standard for determining the eligibility and grant quantum under various green building related incentives. Its assessment framework is also adopted as the compliance method under the current regulatory requirement on environmental sustainability of new and existing buildings.



environmental scorecard to update their environmental performance for each of their buildings. On the aspects of new building construction, the public sector agencies are to take the exemplary lead to ensure that their new buildings with more than 5000 square metres air- conditioned spaces are designed and constructed to attain the Green Mark Platinum rating. As for the existing buildings with more than 10,000 square metres air-conditioned spaces, the public sector agencies will have to make progress in improving the building performance by way of energy efficient retrofitting when appropriate, to attain the Green Mark Gold^{Plus} rating by 2020. These initiatives help create a demand for energy efficient buildings and related services, providing opportunities to influence and to bring about a broader change in the private sector. To further intensify our efforts in view of the rising global concern for environmental issues, Other than fiscal measures and government policies to encourage green building alternatives, regulatory controls were also put in place to help push for a wider adoption of green building technologies and practices in the building industry.

Progressive Legislative Frameworks to drive Environmental Sustainability

Since the energy crisis in the 1970s, BCA has been actively involved in energy conservation in buildings. A set of energy standards was developed and incorporated in the Singapore Building Control Act and Regulations then, with subsequent revisions to keep abreast with advancement in technology and global trends. Reducing the carbon emission levels of buildings through various energy efficiency measures has always been an integral part of Singapore's energy policy. Under the Sustainable Development Blueprint formulated by the Inter-Ministerial Committee on Sustainable Development (IMCSD), the target set for Singapore's built environment is to have *"At least 80% of the buildings in Singapore to achieve the BCA Green Mark Certified rating by 2030"*. To achieve this, BCA has rolled out its Green Building Masterplan, a roadmap that sets out specific initiatives including regulatory measures to achieve a sustainable built environment in Singapore by 2030. To advance sustainable development, the Singapore Building Control Act was revised over time to put in place appropriate legislative controls where market forces would not be sufficient to achieve the optimal level of sustainability in buildings. These legislative frameworks would provide the necessary impetus on the desired reduction in energy consumption and carbon emissions by taking the whole life cycle of buildings into consideration. The legislative frameworks implemented are as follows:

- (1) Mandating a Minimum Environmental Sustainability Standard for Building Development
- (2) Setting Mandatory Higher Green Mark standards for Government Land Sales Sites
- (3) Establishing National Energy Benchmarks through Annual Mandatory Submission of Building Information and Energy Consumption Data
- (4) Prescribing Mandatory Minimum Environmental Sustainability Standard for Existing Buildings Undergoing Installation and Replacement of Cooling Systems
- (5) Closing the Loop by Requiring Mandatory Periodic Audit of Energy Efficiency of Building Cooling System for All Buildings



Mandating a Minimum Environmental Sustainability Standard for Building Development

To step up our efforts in driving environmental sustainability in buildings, BCA has taken the decisive steps to introduce a mandatory minimum standard of environmental sustainability known as the Building Control (Environmental Sustainability) Regulations in Apr 2008. This regulation requires developers and owners of new building projects as well as existing building projects involving major retrofitting (with Gross Floor Areas of 2000 m² or more) to meet the compliance standard which was modelled after the basic Green Mark certified standard. Compliance with the standard is required before building plan can be approved. Site audit will be conducted by BCA where needed to ensure that the design intent for environmental sustainability submitted is implemented before issuance of the Temporary Occupation Permit (TOP).

The minimum environmental sustainability standard covers performance based requirements that necessitate the use of cost-effective energy saving technologies, design strategies, construction methods and operational monitoring. Under this requirement, their design practitioners appointed by the developers or owners would have to ensure that the building design meet at least 28% energy efficiency improvement from 2005 codes along with other salient aspects of environmental sustainability such as water efficiency, indoor environmental quality, environmental management and the use of green building technologies. As building cooling systems can account for more than 50% of the total electricity consumed in a typically air-conditioned building, having more energy efficient ones would help reap a significant portion of the energy savings during building operations. Coupled with the fact that these systems have a long lifespan lasting 15 to 20 years before replacement, it becomes crucial to ensure that new air-conditioning systems installed are of higher energy efficiency in the first instance and subsequently operated in an efficient manner. For this, the standard stipulate the use of better energy efficient air-conditioning systems² to be installed, which would benefit the building owners with more energy savings in the long run.

Recognising the barriers to achieving optimal energy performance during building operations is the lack of adequate metering and energy monitoring equipment, the standard also incorporates provision to require buildings to be equipped with suitable means for the monitoring of energy efficiency of the air-conditioning systems, so as to facilitate energy improvement opportunities. With these devices, building owners would be able to track and pro-actively improve the energy performance of their buildings during operation. On a whole, it is evident that the minimum environmental sustainability standard successfully provided a baseline to drive and integrate green building design and technologies into the mainstream design practices over the years. Integrating the mandatory requirement with the building plan process has also effectively created a greater pool of industry practitioners including builders motivated in green building design and practices. The adoption of the BCA

² The minimum environmental sustainability standard spells out the prescribed air-conditioning system efficiency which are higher than the current code requirement (i.e. SS 530 & SS553) for compliance. For example, air-conditioning system efficiency should be better than 0.7 kW/ton for basic Green Mark project.



Green Mark standard into the legislative framework has also created a common language or platform on sustainability issues among practitioners, providing a consistent approach and drive in accelerating the development of green buildings locally.

Setting Mandatory Higher Green Mark standards for Government Land Sales Sites

With increased capacity and knowledge on the benefits of sustainable development among industry practitioners, BCA has mandated higher Green Mark standards under the Government Land Sales Programme in May 2010, to further enhance the environmental sustainability of our built environment. This requirement applies to key development areas which include Jurong Lake District, Kallang Riverside, Paya Lebar Central and Marina Bay/Downtown Core. This would help achieve a significant impact in energy efficiency improvement of at least 38% over the 2005 codes. The development of these areas in an environmental sustainable manner, could also be showcased locally and internationally as exemplary for sustainable development. Under this requirement, developers who are interested in bidding the lands in these districts are required to ensure their new building developments are certified to meet the Green Mark Platinum or Gold^{Plus} standards as stipulated in the land sale tender conditions. If the developer fails to submit evidence of achieving the intended Green Mark rating, the clearance for Temporary Occupation Permit (TOP) can be held back under the Building Control Act. The minimum environmental sustainability standard spells out the prescribed air-conditioning system efficiency which are higher than the current code requirement (i.e. SS 530 & SS553) for compliance. For example, air-conditioning system efficiency should be better than 0.7 kW/ton for basic Green Mark project.

Establishing National Energy Benchmarks through Annual Mandatory Submission of Building Information and Energy Consumption Data

From 1 July 2013, building owners are required to submit their building information and energy consumption data annually to BCA. In the initial phase, only building owners with hotels, office buildings, retail buildings and mixed developments are required to submit data. The requirement will be further extended to other building types in phases. The intent of this requirement is to establish and facilitate a national energy benchmarking system. The data collected will be shared to enable building owners to benchmark and compare their building performance against other similar building type. This will help motivate them to take proactive actions to improve their building's energy profile and to manage their building's energy cost. With availability of data, BCA will also be able to monitor energy consumption patterns and evaluate the effectiveness of various initiatives that have been adopted to improve energy efficiency in buildings. Currently, the requirement does not directly require public disclosure of the energy performance of individual buildings. Energy consumption data will be obtained from the utility suppliers without the need for building owners to submit the data individually and separately to BCA.

Prescribing Mandatory Minimum Environmental Sustainability Standard for Existing Buildings Undergoing Installation or Replacement of Cooling Systems



As existing buildings constitute more than 90% of our total building stock, there is scope to improve their energy efficiency standard to contribute to Singapore's carbon abatement. It is pertinent to ensure that these buildings are equipped with better building cooling systems when retrofitted and continue to operate efficiently throughout their life-cycle. To improve the energy efficiency standard of existing building, BCA has imposed a minimum environmental sustainability standard based on the basic BCA Green Mark standard for existing buildings with effective from Jul 2013. Building owners will need to ensure that their existing buildings meet this standard when they install or replace their building cooling system. In the initial phase, the requirement to meet the minimum standard will apply to hotels, retail buildings and office buildings with gross floor area (GFA) of 15,000m² or more and in the process of installing/replacing a central air conditioning system. There is also pre-requisite to require the building cooling system installed to meet certain specified design system efficiency (DSE). The standard also prescribes the installation of permanent measurement and verification instrumentation for the monitoring of the energy efficiency of central air-conditioning system.

To comply with the minimum environmental sustainability measures stipulated in the Regulations, the building shall achieve a minimum Green Mark score of 50 points and meet the pre-requisite requirements. Before commencement of the replacement or retrofitting works, the building owner shall appoint a Professional Engineer (Mechanical) to assess the design of the retrofitting works, prepare the Green Mark design score; provide the documentation of the design score that meets the minimum environmental sustainability standard and such other documents required in the Regulations before the commencement of the retrofitting works. The retrofitting work must be commenced and completed not later than the period granted. Upon completion of the installation or replacement works, the Professional Engineer shall assess and prepare the as-built Green Mark score that meets the minimum environmental sustainability standard, and provide to the building owner the documentation of the as-built score, completion certificate and such other documents for submittal to BCA within the period prescribed in the Regulations.

With the requirement to meet the minimum Green Mark standards for buildings undergoing installation/replacement of their cooling systems, building owners can take the opportunity to relook at their existing building cooling systems and make improvements to them and also to other parts of the buildings to achieve greater energy savings. By meeting the minimum standard, building owners can expect to achieve a minimum 25% improvement in energy efficiency as compared to 2005 codes and will stand to benefit from lower energy bills during operation.

Closing the Loop by Requiring Mandatory Periodic Audit of Energy Efficiency of Building Cooling System for All Buildings

While buildings may be designed and installed with energy efficient cooling systems, operating these systems at an optimum performance level would be of paramount importance to ensure that the intended energy savings will be realised. By carrying out periodic energy



audit of cooling systems would help ensure that the systems continue to operate as efficiently as per initial design throughout their life span, allowing building owners to continuously reap the energy saving benefits as intended. With effective from 1 Jan 2014, building owners are required, upon notice from the Commissioner of Building Control, to engage the services of a Professional Engineer (Mechanical) or an Energy Auditor registered with BCA to carry out an energy audit on the building cooling system and to make the energy audit report within stipulated timeframe for approval. For existing buildings which have undergone retrofitting, owners will have to conduct their first energy audit of the building cooling system together with the submission of the as-built Green Mark score upon completion of the retrofitting works; and subsequently, to conduct energy audits in 3 yearly intervals from their last audit. As for new buildings with centralised chilled-water cooling system which are required to comply with the enhanced Green Mark standards for new buildings implemented on 1 December 2010, building owners will have to conduct their first audit within one year from the date of the first temporary occupation permit or certificate of statutory completion; and subsequently, to conduct energy audit of the system in 3 yearly intervals from the last audit. If the cooling system does not meet the applicable prescribed energy efficiency standard, building owners would have to take measures in relation to the cooling system to ensure that it meets the applicable prescribed standard.

Conclusion

Singapore is one of a very few countries to close the loop by ensuring that a building that is designed and constructed as a green building would continue to operate efficiently through its life cycle. Under this legislation in Singapore, a building is required to be retrofitted to meet a minimum environmental sustainability standard, when it undergoes installation/replacement of its cooling system. This innovative measure will raise the overall building's energy efficiency from the beginning. Coupled with the three-yearly energy audit of the cooling system (which constitutes usually 50% to 60% of a total building's energy consumption), a building can remain energy efficient throughout life cycle. At the end of its life cycle, the process would repeat itself, as a building would again be retrofitted to high energy efficiency standards to comply with the minimum environmental sustainability standards.

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Sustainability Labelling for Building Standards

Note: This paper has been peer reviewed by the World SB14 Barcelona Scientific Committee

Author:

Bill DODDS, Scottish Government, Building Standards Division, Local Government and Communities, Denholm House, Almondvale Business Park, Livingston, EH54 6GA, Scotland (Bill.Dodds@scotland.gsi.gov.uk) – Sustainability Labeling for Building Standards

Abstract: *In Scotland building regulations set standards for the health, safety and welfare of persons in and around buildings, furthering the conservation of fuel and power and furthering the achievement of sustainable development. These standards are supported by guidance contained in a set Technical Handbooks, and apply to new buildings and to buildings being converted, altered or extended. In May 2011 sustainability labelling was introduced to Scottish building regulations. Applicable to all new buildings, the principles build upon the degree of sustainability already embedded within the building regulations. The labelling system in Section 7 of the Technical Handbooks rewards new buildings that meet the 2010 building standards with a Bronze level label. Further optional upper levels are defined by Silver, Gold and Platinum. These have been created through identifying cost-effective benchmarks verifiable through the building standards system. Section 7 has been fully developed for dwellings and school buildings. However for all other non-domestic only carbon dioxide (CO₂) emissions can be assessed. Section 7 also includes an indicator that identifies whether buildings incorporate a low or zero carbon generating technology (LZCGT). The criteria for each sustainability level seeks to balance the social, economic and environmental aspects associated within the scope of sustainability, addressing issues such as resource use through carbon dioxide emissions, energy efficiency and water use, enhanced biodiversity, improved occupant wellbeing, and flexibility and adaptability in design.*

Introduction

Sustainability is a broad and complex term that means different things to different people. Addressing issues such as climate change, pollution, the wasteful use of finite resources, population well-being, habitat destruction and species loss, as well as the harnessing of renewable energy. However the fundamental aim of sustainability is to live within the capacity of the planet and secure a future for forthcoming generations. More often than not it is simply a worthy lesson in common sense. The definition for sustainable development is neatly reinforced in the Brundtland commission's report.

“meeting the needs of the present without compromising the ability of future generations to meet their own needs”

Brundtland Commission of U.N 1983

It is therefore prudent that the process of sustainable development and the quality of 'sustainability' within the built environment should account for:

- social, economic and environmental factors;
- the potential for long-term maintenance of human wellbeing in and around buildings;
- the wellbeing of the natural environment and the responsible use of natural resources;
- the capability for the built environment to be maintained.

Sustainable buildings have a positive impact on occupant well-being, whilst minimising the use of finite resources including land and water, as well as fossil fuels which are a major contributor to carbon dioxide (CO₂) emissions and Climate Change. For a building to be considered sustainable, it must demonstrate that a wide range of factors are considered in its design and construction. The building standards in Scotland focus specifically on buildings and their immediate curtilage, therefore a bottom-up approach was devised for developing a framework for measuring and assessing sustainable buildings.



Figure 1 - Sustainable model for Scottish Government

Defining sustainability for building standards

When the Scottish Government's Building Standards Division sought to define sustainability for the built environment it was established that the approach to sustainable development should be holistic encompassing a large number of topics (see fig 2), However to avoid these topics becoming meaningless they need to be broken into defined parts . Some of the issues to be addressed in defining sustainability in the built environment were considered to be easily quantifiable such as, structure, noise and land use, and some less so, such as cultural activity and amenity but all issues matter to some degree when trying to balance sustainability. Each of the topics can be broadly addressed in each of the following statutory processes:

- 1st statutory application: Planning Permission - addresses issues relevant to land use, location and amenity
- 2nd statutory application: Building Warrant (permit) – addresses technical detail on the construction and layout of individual buildings

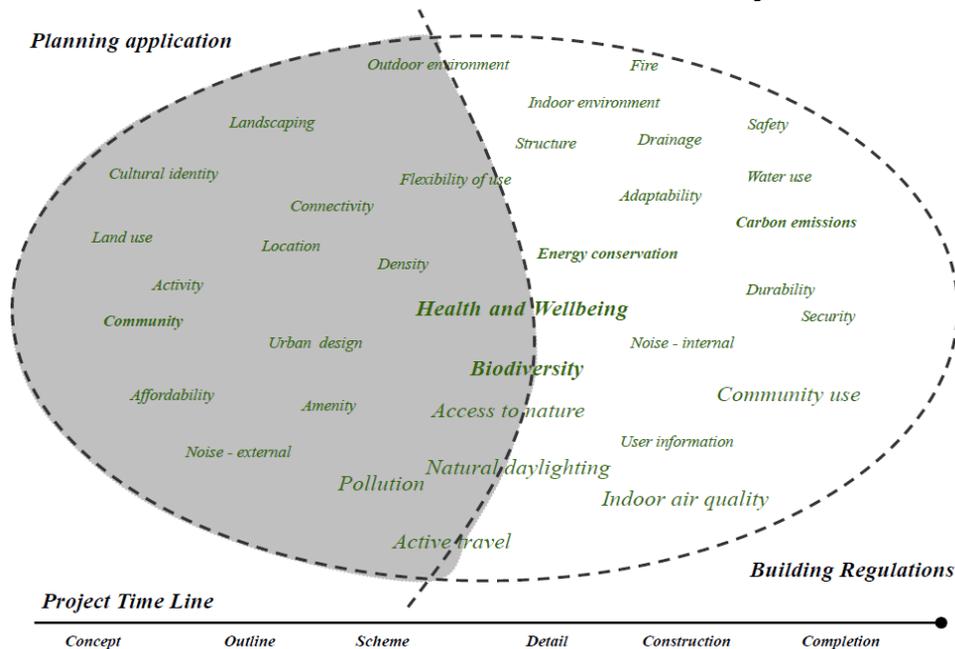


Figure 2 – Topic Cluster

From the above cluster, sustainability for building standards was able to be distilled from the topics into 3 key areas:

- Resource use – including energy, water, fuel and land use looking at how finite resources are accessed
- Well-being – improving quality of life and being able to deliver lasting benefits to building occupants and users
- Flexibility – maximising the efficiency of building by encouraging buildings to be able to be used for multiple purposes

Drivers and influences and how these helped shape proposals

The key purposes of the Building (Scotland) Act is to:

- Secure the health, safety, welfare and convenience of persons in or around buildings:
- Further the conservation of fuel & power and
- Further the achievement of sustainable development.

The Act was the first clear driver that enabled sustainability to be addressed through building standards. Prior to 2011, this had been addressed by progressively embedding sustainability aspects within building standards. A further driver was the Sullivan report. The report was the output produced by an expert panel appointed by Scottish Ministers to advise on a low carbon buildings standards strategy for Scotland. It made recommendations across a wide range of topics, including on the delivery of very low carbon buildings through building regulations, in support of climate change objectives. A further legislative driver was the Climate Change



(Scotland) Act 2009, this set a framework allowing Scotland further responsibility for their Green House Gas emissions by setting legally binding targets to reduce emissions and mitigate climate change. The fourth and probably most important driver/influence is market demand, this set aspirational design levels beyond minimum regulations and standards and allows applicants to gain formal recognition for achieving so. For example environmental assessment methodologies such as, Passiv-haus, BREEAM and LEED are very useful tools which demonstrate the complexities in addressing sustainability through the built environment.

Sustainability for building standards

The introduction of sustainability labelling enabled Building Standards to measure, encourage, and recognise sustainability in the construction process. Voluntary upper levels were developed in conjunction with industry, by identifying cost-effective benchmarks verifiable via the building standards system. This allowed those with environmental ambitions to demonstrate their ‘green’ credentials by encouraging:

- lower carbon buildings;
- efficient use of resources such as energy and water; and;
- progressive sustainable design

Although energy efficiency and CO₂ emissions forms a key part of any sustainability agenda, it was established for a building to achieve an enhanced levels of sustainability , it must be demonstrated that a balanced range of measures have been considered in design and achieved in construction.

How does it work? Levels of sustainability

In 2011 sustainability labelling was included in the Technical Handbooks, this awarded new buildings that met the 2010 building standards with a Bronze level label. Further optional upper levels of sustainability were defined by Silver, Gold and Platinum labels (see fig 3). The labelling system also includes an indicator for buildings which incorporates a low or zero carbon generating technology (LZCGT) identified with an ‘Active’ marking. The initial level of sustainability labelling (the ‘bronze’ level) which all buildings will achieve demonstrates that a building complies with the minimum building standards applicable at the time of application. The rationale for this is to differentiate between buildings constructed prior to 2010 and acknowledge the considerable improvements recently made to standards. These include improvements to energy standards, adoption of some of the lifetime homes principles and improved security standards.



Figure 3 - Sustainability levels

The ‘silver’ and ‘gold’ levels are voluntary defined by criteria relating to the design and construction process. The Silver level has been developed to recognise best practice in the industry, and encourage those who may not typically wish to build beyond minimum regulations. The gold level has been set as a more challenging and demanding target to promote and reward those seeking to produce exemplar buildings. A Platinum level has been identified for future scope and development.

The Sustainability labelling system was fully developed for domestic buildings and a CO₂ Aspect introduced to all non-domestic buildings. For October 2013 sustainability labelling for school buildings was developed on the principles explored for domestic buildings with the intention of this being a pathfinder to expand sustainability to other non-domestic buildings. Issues defined within building standards legislative control were identified. These can be assessed by verifiers during the building standards process. ‘Aspect’ is the term used for a subject area of sustainability (see fig 4). Level is the term used as a grouping, where all of the 8 individual aspects of sustainability have achieved the criteria set out in the guidance. To obtain a label the level of sustainability must be specified during the design stage, the building will have to be constructed in accordance with the drawings and specification. On completion a sustainability label is created using customised software and the label affixed to a building and a copy sent to a register. Sustainability labelling for building standards differs from other existing voluntary codes (e.g. BREEAM) which allow for the trading off of topics against each other. The labelling system has fixed requirements all of which must be achieved in order to achieve each level. Each aspect addresses issues which are directly allied to the building standards system and relate to the technical, environmental and functional performance issues of design and construction as well as supporting this with information useful in the efficient operation of a building. The validation of the system is part of the normal building warrant process therefore to achieve an upper level of sustainability an additional assessment fee is not required. The eight aspects for both domestic and non-domestic school buildings are summarised in the table below.

Domestic	Non-Domestic (school buildings)	
Carbon dioxide emissions	Carbon dioxide emissions	
Energy for space heating	Energy efficiency	
Energy for water heating	Water efficiency	



Water use efficiency	Biodiversity	
Optimising performance	Optimising performance	
Flexibility and adaptability	Flexibility and adaptability	
Wellbeing and security	Wellbeing	
Material use and waste	Material use and waste	

Figure 3 - Sustainability Aspects

Who is it for?

Sustainability labelling can be utilised by developers or planners who may wish to demonstrate their environmental commitment by referring to the sustainability labels. The system can also be used by Local Authorities or developers to gain recognition for building to higher standards and potentially to obtain market advantage. Organisations’ funding bodies may choose to make constructing to higher level of sustainability a condition of statutory approval or funding. The topics included have been developed to complement and support other initiatives that promote sustainability. The introduction of the labelling systems also increases the likelihood that sustainability is considered as a first principle during the design process.

Benefits

In Scotland Building Standards are recognised as effective, and valued by industry and the public alike. By continuing to embed sustainability within regulations rather than referring to other environmental standards is considered valuable, and the continuity this brings is welcomed. This has been well received by industry for its clarity and ambition. Sustainability labelling does not need to be an additional burden on development as the initial level of award (bronze and bronze active) recognises that a development has already achieved a measure of sustainability by simply complying with current building regulations. One of the advantages of the system is that it removes the need for the involvement of external assessors such as those used in the delivery of environmental assessment methodologies such as BREEAM. The process is delivered through the existing Building Standards system, verified by each Local Authority as part of a statutory application required by law and intended to deliver a consistent national sustainability standard.

The system was developed to offer convenience and simplicity as well as adding little or no additional cost to the design and verification process other than for those who opt to achieve the higher levels. The structure was designed to enable each of the 8 individual aspects of sustainability to be clearly identified, easily measured, and even referred to individually where required. With energy standards continuing to improve and the introduction of the Climate Change (Scotland) Act 2009, there are signs that Local Authorities are less inclined to create their own carbon reduction targets applicable to individual buildings. A single national standard for sustainable buildings points towards a more measured approach. Some Planning departments have referenced the Building Standards sustainability standards when preparing policies on carbon reductions within Local Development Plans. The more recent



development of introducing sustainability for all aspects of new non-domestic school buildings would provide a system that could be used consistently throughout Scotland aligning with calls from funding bodies. Without Scottish Government intervention, sustainability labelling will only be the preserve of those who are prepared to pay extra for an assessment. This also supports many of the Scottish Government's Strategic Outcomes. The range of topics addressed in sustainability labelling was developed following considerable discussion and collaboration with other Scottish Government departments and associated agencies. In many instances organisations were able to refer to aspects of the sustainability system in support of their Policy delivery. For example Scottish Water have provided funding to install the water efficiency measures defined in new social housing. Also, measures that formed part of the voluntary upper levels of sustainability for water efficiency have now been incorporated into building regulations. Additionally the Scottish Government Division responsible for social housing have made available funding for newly constructed social housing to meet the first voluntary upper levels for CO₂ emissions and energy efficiency standards. Included as part of the sustainability criteria for new school buildings is the provision of a user guide to enhance biodiversity and promote ecology. This has received broad support from Scottish National Heritage (the national body responsible for promoting and caring for the natural heritage) and widely promoted by the Scottish Government across the existing school estates. The system was also developed to give planning authorities a consistent route to achieve their obligations under Section 72, of The Climate Change (Scotland) Act 2009 in relation to the use of low and zero carbon generating technologies. Scottish Government is now in discussion with the Building Research Establishment to incorporate sustainability labelling within BREEAM for Scotland, this will allow those seeking to address issues of sustainability not verifiable through building regulations the opportunity to do so.

Summary of key benefits

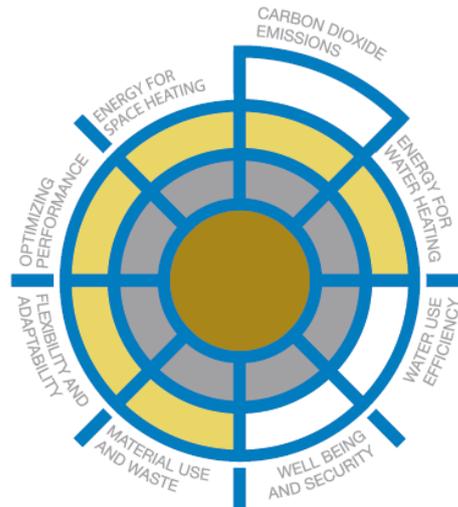
- Obtaining recognition in achieving the level of sustainability achieved by meeting the current building regulations, without additional assessment costs.
- Providing home buyers and building owners, directly, with information on the level achieved.
- Setting standards to allow industry to achieve aspirational upper levels of sustainability, which would be officially recognised.
- Providing a simpler approach to achieving sustainability compared to other more complex and tradable assessment processes.
- Creating a 'level playing field' for all of industry, not disadvantaging either smaller or larger businesses.
- Reducing carbon dioxide emissions and energy demand from new buildings, when constructed to the silver and gold levels.
- Supporting the Government's agenda to tackle climate change and promoting sustainable development in Scotland.



- Reducing use of finite natural resources and promoting development and adoption of systems that incorporate renewable energy sources.

Building Standards Sustainability

At completion, the building achieved the specified level of sustainability in the aspects below:



■ Platinum
 ■ Gold Partly Achieved
 ■ Silver Achieved
 ■ Silver Active Achieved by use of the following technology:
 solar thermal panels
 ■ Bronze Sections 1-6, 2010 Standards

Building / Development:

Building Warrant Reference:

Date:
 15 June 2011

Building Standards Division's Technical Handbooks

Contain detailed guidance on the measures to achieve the levels within each aspect of sustainability. See Building Standards pages on www.scotland.gov.uk

This statement of sustainability for a new building must be fixed within the building in accordance with standard 7.1.





Building Regulatory Control in Facing the Challenge of Climate Change: a case of Hong Kong

Note: This paper has been peer reviewed by the World SB14 Barcelona Scientific Committee

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Abstract: *Facing the challenge of climate change, global actions are required to reduce energy consumptions in various economic sectors. Buildings consume a significant amount of electricity generated from fossil fuels, and governments worldwide are seeking solution to reduce energy consumption in buildings. Buildings worldwide not only exhibit poor energy performance, but also pose adverse impacts to the built environment. This paper review the regulatory control for buildings in Hong Kong in the face of climate change and the findings are commented with suggestions for further study.*

Keywords: *Buildings Ordinance, Building Energy Efficiency, Overall Thermal Transfer Value, building environmental assessment*

Introduction

The residential and commercial buildings sector in many countries consumes 25 – 50% of the total energy of the countries and contributes a significant amount of GHG emissions (OECD, 2003). Like many cities, the building sector In Hong Kong consumes most of the total energy and contributes a significant proportion of GHG emissions, and thus implementation of appropriate regulatory control of energy conservation in buildings is a significant concern of local governments. This paper provides an overview of the regulatory control on buildings in Hong Kong Special Administrative Region (HKSAR) in response to the mitigation of climate change. Since early 1990s, green building practice has been emerging to address the issues of the negative impacts posed by the building construction to the built environment. Green buildings pursue efficient use of land, energy, water and natural resources, improvement of indoor and outdoor built environment. However, the interpretation of green buildings can be various, and sometimes the terms green buildings and sustainable buildings are used vice versa (Adshead, 2011). These buildings involve evaluation of a majority of interactions between buildings and their environments. Moreover, one of the key characteristics of green buildings is to use energy more efficiently than conventional buildings, otherwise it is not persuasive that green buildings are actually green (Howe and Gerrard, 2012). The publication of Building Research Establishment Environmental Assessment Method (BREEAM) of Hong Kong in 1990, attempts to establish comprehensive approach to assess a wide range of environmental performance of buildings emerged (Cole, 1998).

Buildings Energy Efficiency in Hong Kong



Implemented on 16 February 2005, the Kyoto Protocol defined binding obligations on developed countries for the reduction of GHG emissions by an average of 5.2% (UNFCCC, 2013). China ratified the Kyoto Protocol as a developing country (Non-Annex I Party) on 29 May 1998 (China Daily, 2000). Under the Protocol, China has no binding reduction target of GHG emissions to be achieved. Although Hong Kong, being a special administrative region of China, is not a party to the Kyoto Protocol, the Central Government of China decided according to Article 153 of Basic Law of Hong Kong, that the Kyoto Protocol shall be applied to Hong Kong with effect from 5 May 2003 (EPD, 2007), even though there is no binding GHG emissions reduction target to be achieved by Hong Kong. However, as a member of the Asia-Pacific Economic Co-operation (APEC), The Government committed on 8 September 2007 in the APEC Leaders' Declaration on Climate Change, Energy Security and Clean Development held in Sydney to achieve a reduction in energy intensity of at least 25% from 2005 level by 2030 (China View, 2007; EPD, 2008). The energy intensity is referred to as amount of energy end-use consumed in producing a unit of gross domestic product (EMSD, 2013). In September 2010, The Government issued *The Hong Kong's Climate Change Strategy and Agenda Consultation Document 2010* in which, The Government aimed at reducing the energy intensity of the territory by 50% - 60% by 2020 as compared to 2005 (HKSAR, 2010).

Intensive Energy Consumption and GHG Emissions

The energy types available to Hong Kong are mainly oil and coal product, town gas and liquefied petroleum gas (LPG), and electricity (EMSD, 2013). While the consumption of oil and coal products was decreasing, and the usage of town gas and LPG was at a steady rate, the electricity consumption in Hong Kong was increasing rapidly. Statistical records revealed that electricity consumptions were 48% in 2000 and 54% in 2010 of the total energy consumption of the territory. The rate of increase was amount to 1.5% per year as compared to that at 2000, and 1% per year as compared to that at 2005. The saving of consumption of oil and coal products was offset by the increases in the consumptions of electricity. Moreover, there is no sign of decrease in electricity consumption (EMSD, 2013). The key sectors of electricity consumption in Hong Kong are residential, commercial, industrial, and transport sectors (EMSD, 2013). The first and second sectors are generally referred to as building sector which is the biggest electricity consumer among the other two sectors. Electricity consumption in building sector is mainly for the space conditioning, lighting, refrigeration, cooking, water heating, office equipment, laundry and industrial process. And the building sector consumed more than 90% of total electricity consumptions of the territory since 2007, and 92% in 2011. As at 2010, the rates of increase in electricity consumption are 26% and 10% as compared to 2000 and 2005 respectively. As far as GHG emissions are concerned, the total GHG emissions in Hong Kong grew from 35,300 kilotons in 1990 to 41,500 kilotons in 2010. Figure 1 illustrates the increasing trend of GHG emissions in Hong Kong for the period between 2000 and 2010. With reference to the distribution of different energy types and the amount of electricity consumption in building sector, the contribution of GHG emissions by

the building sector can be amounted to 60% (HKSAR 2010). Therefore the building sector in Hong Kong provides a challenge to large scale reduction of GHG emissions.

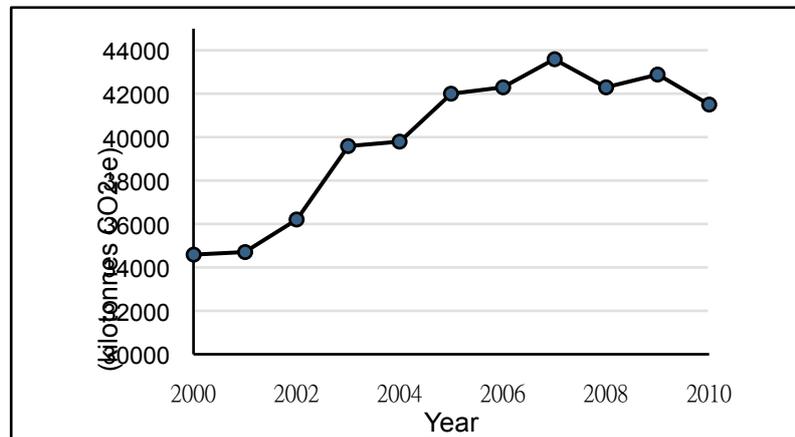


Figure 1 – GHG emissions (in terms of Carbon) in Hong Kong [Data retrieved from (EMSD, 2013a)]

General Framework for Building Controls in Hong Kong

The earliest legislations related to building construction were probably the ‘Ordinance for the Preservation of Order and Cleanliness within the Colony of Hong Kong’ enacted in 1844, ‘Buildings and Nuisances Ordinance’ enacted in 1845, and ‘Public Health Ordinance’ in 1887. These legislations set out requirements for the construction of buildings and the associated basic sanitary facilities as overcrowding and insanitary living environment were prevailing in those years. Since 1889, Buildings Ordinance was firstly promulgated to improve the structural stability and sanitary condition of buildings. Although major amendments of the Ordinance were then made in 1935 and 1955, the control of buildings was closely linked to matters relating to structural safety, fire safety and sanitation of buildings (McInnis, 2000). The current regulatory control of the planning, design and construction of buildings comprise four major instruments enforced by the Building Authority. These instruments are:

- The main legislation
- Subsidiary regulations
- Code of Practice
- Practice Notes

Regulatory Control of Energy Conservation in Buildings

Following the first oil crisis in 1973, The Government issued in 1979 guidelines for the design of electrical installation in government buildings as a first step towards energy conservation in buildings (EMSD, 2004). In 1995, the Government enacted Building (Energy Efficiency) Regulation (B(EE)R) which requires building envelope of commercial buildings and hotels shall be designed with a suitable Overall Thermal Transfer Value (OTTV). Under the B(EE)R, OTTV is defined as the amount, expressed in watts per square metre (W/m²), of



heat transferred through that building envelope and calculated having regard to factors such as the area of the building envelope, the material used in its construction, thermal properties of the material, orientation of the building, the area of the openings in the building envelope and the shading effect of projections from the building envelope. In other words, the OTTV represents a measure of thermal transmission through the façade and roof of a building, and implies that the lower the OTTV the better thermal performance of a building (Building Authority, 1995). Under the Buildings Ordinance and B(EE)R, the OTTVs of all new commercial buildings and hotels are subject to approval prior to application for the commencement of the construction of the commercial buildings and hotels (PNAP No. APP67, 2011). In practice, suitable OTTV of commercial buildings and hotels are applied to the tower portion and podium portion of the building, and stipulated in Code of Practice of Overall Thermal Transfer Value in Building 1995 issued by Buildings Department. Table 1 tabulates the suitable OTTV of the requirements.

Application of OTTV	Effective from year		
	1995	2000	2011
In the case of a building tower	35 W/m ²	30 W/m ²	24 W/m ²
In the case of a podium	80 W/m ²	70 W/m ²	56 W/m ²

Table 1 – Overall Thermal Transfer Values for Commercial Buildings and Hotels

In addition to OTTV control, EMSD published the following voluntary building energy codes: the Code of Practice for Energy Efficiency of Lighting Installations in 1998, the Code of Practice for Energy Efficiency of Air Conditioning Installations in 1998, the Code of Practice for Energy Efficiency of Electrical Installations in 1999, and the Code of Practice for Energy Efficiency of Lift and Escalator Installations in 2000.

As the five Code of Practice issued by the Buildings Department and EMSD are principally prescriptive standards, EMSD further issued Performance-based Building Energy Code (PB-BEC) in 2004. By the performance-based approach, the overall energy consumption is allowed to be estimated taking into account of thermal transfer through the building envelope and the energy consumption of electrical equipment including the lighting, air-conditioning, fixed electrical, and lift and escalator systems. In other words, designers are allowed to adopt flexible approach in designing the energy efficiency in buildings (EMSD, 2007). The Government further enacted in September 2012 Building Energy Efficiency Ordinance (BEEO) requiring developers of new building projects and major retrofitting projects to submit declaration notifying compliance the requirements of the relevant building energy codes. Under the BEEO, the coverage of regulatory control has been extended from commercial buildings and hotels to include common areas of residential and industrial buildings, schools and hospital (BEEO, 2010). Under the BEEO, owners of commercial buildings and hotels shall made first declaration to EMSD within 2 months from the date of granting consent for the commencement of the construction of the building works granted by the Building Authority, and the second declaration shall be submitted to EMSD within 4 months from the date of obtaining occupation permit of the building granted by the Building



Authority. The BEEO also mandates commercial buildings to conduct energy audit every 10 years (EMSD, 2013b).

Policies and Incentives to Promote Green Building

In April 2009, the HKSAR government launched the “Buildings Energy Efficiency Funding Scheme (BEEFS)” allocating with HK\$450 million funding in order to provide financial incentive to owners of private buildings to conduct “Energy-cum-carbon Audits Projects” and “Energy Efficiency Improvement Projects” (ECF, 2013). The Energy-cum-carbon Audit Projects aimed at encouraging owners of existing buildings to carry out systematic review of energy consumption and GHG emissions and identify opportunity for improvement of energy efficiency and reduction of GHG in their buildings. Under the Scheme, the common areas of residential, commercial or industrial buildings were covered. Furthermore, the audit should be carried out in accordance with the requirements of “Guidelines to account for and report on GHG Emissions and Removals for Building (Commercial, Residential and Institutional purposes) in Hong Kong; and Guidelines on Energy Audit published by The Government of HKSAR (ECF, 2013). Energy Efficiency Improvement Project intended to encourage owners of existing buildings to upgrade the energy performance of lighting, electrical, air-conditioning and lift and escalator installations of their buildings through the carry out of alteration, addition or improvement works. Under the Scheme, applicants were required to engage qualified persons to certify the scope of the project, justify cost effectiveness, supervise and certify completion of the improvement works. There were requirements that on completion of the project, the fixed electrical equipment or installations had to comply with the standards stipulated in the building energy codes issued by the EMSD (ECF, 2013). However, the BEEFS only covered the communal areas of buildings and was terminated in April 2012. By the end of April 2012, there were 72 applications for Energy-cum-carbon Audit Projects and 984 applications for Energy Efficiency Improvement Projects approved (ECF, 2013).

In 1996, a non-profit organization HK-BEAM Society launched a scheme known as Building Environmental Assessment Method (BEAM) for assessment of environmental performance of office buildings. Following several updates and revisions, the current version of the assessment scheme is renamed as “BEAM Plus” and embraces a wide range of new and existing buildings, including residential, commercial, institutional, and industrial buildings (BEAM, 2013). In 2009, The Government announced that all new government buildings with construction floor area more than 10,000 square meters should aim to obtain at least ‘Gold’ rating under BEAM Plus (HKG Press Release, 2009). Furthermore, since 2011, the Building Authority allows curtain walls to be projected over streets if the curtain walls meet certain standard of the BEAM Plus (PNAP APP-2, 2011). The assessment of BEAM Plus covering energy efficiency aspect and conferred by the HKGBC is also considered as requirement for granting additional floor areas of building projects (PNAP APP-151, 2011). In addition, there are other key Initiates for Building Energy Efficiency including:

- *Wider Use of Water-Cooled Air Conditioning System:* a ‘Pilot Scheme for Wider Use of



Water-Cooled Air Conditioning System' was launched in 2000.

- *Energy Efficiency Registration Scheme for Buildings*: since 1998, the EMSD established an Energy Efficiency Registration Scheme for Buildings in 1998.
- *Energy Audit Program*: from 1994, the EMSD conducted survey of all major government buildings.
- *Establishment of Appliance and Equipment Labeling Scheme* : since 1995 EMSD has administered a voluntary scheme for energy labeling of appliances and equipment used in home and office.

Future Development

Although the regulatory control of the planning, design and construction of buildings in Hong Kong has been amended since 1995 to address the energy conservation in buildings, there are critics about the control system, incentives and the initiatives. As observed by Adshead (2011) that coupling with the issue of energy efficiency in buildings are that buildings: (a) consume a great amount of natural resources in terms of land, natural material, and water resources; (b) generate a great amount of solid waste, and sewerage; and (c) emit large quantities of pollutants (UNEP 2007a, OECD 2003). Adoption of green building practice rather than sole regulating the energy efficiency of building is recognized as a key strategy to tackle the climate change (Adshead, 2011). The Government of HKSAR issued in 2010 consultation document named “The Hong Kong’s Climate Change Strategy and Agenda Consultation Document 2010” in which, the following relating to energy use in buildings have been proposed by HKSAR: promoting use of energy meters, sensors and communication links that help property management to control energy consumption in major equipment in commercial buildings; and, expanding the current energy labeling scheme for electrical appliances.

Conclusion

The current regulatory control of the buildings is administrated under the Buildings Ordinance which is originated from the legislations that aim at improving the structural safety, fire safety and sanitary conditions of the built environment. The Government made a major amendment to the Ordinance and enacted a few building energy efficiency related regulations over the years to address energy conservation in buildings. Until the implementation of Building Energy Efficiency Ordinance in 2012, methodology for complying with the requirements stipulated in Building (Energy Efficiency) Regulation includes performance-based approach by which the overall energy consumption may take into account of thermal transfer through the building envelope and the energy consumption of electrical equipment including air-conditioning system. Although various measures or initiatives have been adopted by The Government, most of them are not building works related. Future studies should embrace innovation in the current building control system of Hong Kong to achieve large scale enhancement of the built environment.

Acknowledgement

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Sustainability, resilience and risk in earthquake-prone areas: Lessons for building regulators from the Canterbury earthquakes

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Mike STANNARD, Chief Engineer, Ministry of Business, Innovation & Employment (MBIE), New Zealand (Mike.Stannard@mbie.govt.nz) – *Sustainability, resilience and risk in earthquake-prone areas: Lessons for building regulators from the Canterbury earthquakes*

Abstract: *The Canterbury earthquake sequence has been an outlier internationally in both scale and complexity of consequences. Using a risk, resilience and sustainability framework, issues are highlighted and lessons drawn for building regulators addressing natural hazards.*

Key words: *Canterbury earthquakes, risk, resilience, sustainability*

Introduction

This paper discusses issues and initiatives as a result of the Canterbury earthquake sequence commencing September 2010 using a risk, resilience and sustainability framework. Initiatives are on-going and many remain unresolved. This paper aims to provide some insights to building regulators, particularly to those in areas of earthquake risk.

Background

The Canterbury earthquake sequence began at 4:36am on 4 September 2010 with a damaging M_w 7.1 earthquake situated in Darfield on the Canterbury Plains, on the east coast of the South Island of New Zealand. The epicentre occurred approximately 30 km from Christchurch, New Zealand's second largest city. New Zealand is a seismically active country being situated on the boundary of the Pacific and Australian tectonic plates and thousands of earthquakes are experienced every year, most being of small consequence.

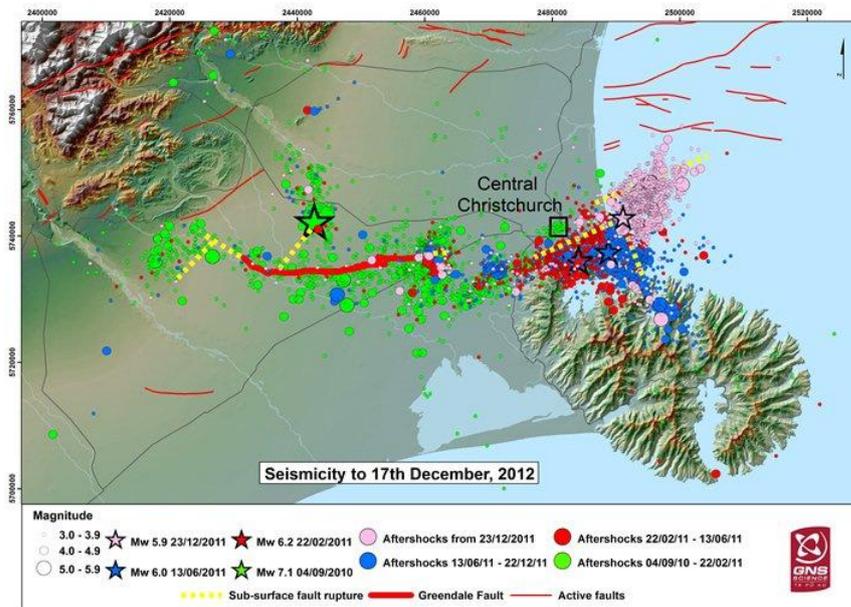


Figure 1 – Canterbury earthquake sequence 2010-2012

This was the most significant earthquake experienced in an urban environment in New Zealand since the Napier earthquake in 1931. The Darfield earthquake, being early in the morning when few people were about, resulted in no loss of life and very few injuries. It did result in significant building damage, mainly to those older buildings constructed in unreinforced masonry. There was also widespread damage to houses on the loose saturated sandy or silty soils of the Canterbury Plains from liquefaction and lateral spreading (Leeves 2012). A significant aftershock caused further damage to the Christchurch CBD on 26 December, 2010 and then on 22 February 2011 the devastating M_w 6.3 Port Hills earthquake resulted in further widespread damage, the collapse of two commercial buildings (CTV and PGC) in Christchurch and the death of 185 people. Some of the highest recorded ground motions anywhere were recorded (2.1g vertical and 1.8g horizontal). Significantly more land damage (liquefaction, lateral spreading, slope stability failure and rock roll) occurred. Two further significant earthquakes occurred on 13 June 2011 and the latest major event on 23 December 2011. There have been some 14,000 events during the sequence, refer Figure 1.

The intensity, on-going nature, and the level of ground damage in an urban environment make the sequence a ‘black swan’ event, truly an outlier of unexpectedly large magnitude and consequence (Taleb, 2001). The current NZ Treasury estimates of the costs amount to \$NZ40B (\$US34B), approximately 20% of NZ’s GDP. There has even been recent speculation that the final costs may mount to \$NZ50B.

The recovery is now into its fourth year and reasonable repair and rebuilding progress on the ground is being made. Many challenges remain, with some of the ‘wicked’ problems still to be solved. While New Zealanders have always been aware of earthquake risk, the impact on Christchurch and its residents has affected the general New Zealand attitude to earthquakes. The Canterbury rebuild and implementing lessons from the sequence are high government priorities.

Risk, resilience and sustainability framework

Illustrating some of the issues that have faced the NZ government and the people of Christchurch, a risk, resilience, sustainability framework is used, refer Figure 2. (Blake 2013)

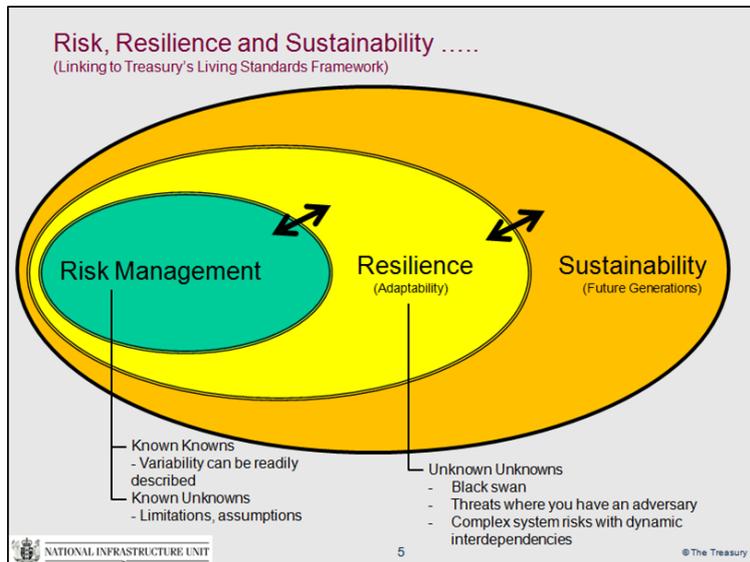


Figure 2 – Blake/Fairclough 2013

While there may be points of contention with this model at a detailed level – buildings constructed for low carbon emissions are not necessarily resilient – it is useful at a conceptual level to provide some coherence to the relationship between risk, resilience and sustainability. The NZ Treasury proposition in explaining their Higher Living Standards framework “is that by practising resilience, we are enabling sustainability and focusing on resilience will be a step towards thinking about sustainability”. (Blake 2013)

Risk

The earthquake hazard is well researched in New Zealand (Stirling GNS 2010) and New Zealand has been at the forefront internationally of seismic engineering design of structures. Design codes are well developed, both to quantify the hazard by location – demand on buildings – and to provide design methods – building capacity (NZS 1170, etc.). Modern code complying buildings are therefore well capable of resisting significant earthquake shaking. Extreme, rare events may well overwhelm the capacity of any building and cause damage and casualties, the case in Christchurch with the CBD now largely demolished.

Even the liquefaction hazard was reasonably understood in Canterbury. A number of liquefaction reports and maps had been produced from the early 1990s and liquefaction had occurred in the Canterbury Plains following earthquakes from the late nineteenth century (Brackley 2012). However, the impact of liquefaction hazard on the development of urban Christchurch was seriously underestimated. Most modern commercial or industrial development had considered liquefaction in the design to some degree, but it was not specifically recognised as a requirement in the Building Code or its supporting documents.



New Zealand also has a strong civil defence framework using the 4Rs: Reduction (identifying and reducing the impact of hazards); Readiness (developing operational capability before an emergency occurs); Response (actions taken during or directly after an emergency); Recovery (activities after initial impact stabilised until community's capacity for self-help restored). (MCDEM 2002).

Reduction: The Building Act, Code and building control process to provide minimum requirements for standards of construction are factors in reducing earthquake risk for new building work. These are informed by hazard, materials and engineering systems research. Lessons from observations, investigations and research are being drawn from Canterbury and improvements to codes and standards will be made as lessons are understood and implemented. This is addressed in more detail below under the section on resilience. New Zealand also legislates to reduce the seismic risk of existing buildings. As a result of the Canterbury earthquakes, regulations are being considered by Parliament to reduce the time owners have to strengthen earthquake-prone buildings.

Readiness: This includes having plans in place for effective local, regional or national response to the emergency. A National Civil Defence Emergency Management Plan provides a framework for the civil defence and emergency management sector in implementing emergency management practices and solutions across New Zealand. New Zealand also has a long history of learning from earthquakes elsewhere by sending reconnaissance teams to observe and sometimes assist (e.g. Maule, Chile; Padang, West Sumatra; Northridge and Loma Prieta, California; Kobe and Tohoku, Japan) normally through the auspices of the New Zealand Society for Earthquake Engineering and the Earthquake Commission (EQC). These have all strengthened New Zealand's capacity to manage in the event of emergency, either from direct lessons or by providing people with necessary experience. The post disaster building evaluation process (tagging) used in Christchurch, was developed with international collaboration, drawing from North American documents (ATC 20) and the experience from other earthquakes. To contribute to readiness for next time, this process is being given statutory recognition in the Building Act, and a summit group of experienced people is being established by MBIE to support any response.

Response: Many lessons have also been drawn from the response phase of the earthquake sequence. Local and regional states of emergency have been declared under the Civil Defence & Emergency Management Act on a number of occasions. However, the February 2011 Port Hills earthquake was the first time that a national state of emergency had been declared. Reviews into the response to the Canterbury Earthquakes have identified improvements to be implemented, including civil defence & emergency management and the Fire Service handling of the CTV building collapse (McLean & Oughton, Pilling, Coroner).

Recovery: The recovery in Canterbury is a huge and complex task. A new government department, the Canterbury Earthquake Recovery Authority, was created by Act of Parliament providing powers to work with partners to coordinate an efficient and effective



work programme for recovery. The recovery strategy includes leadership and integration, economic, social, cultural, built environment and natural environment issues. A Christchurch Central Recovery Plan has been developed following extensive public consultation. Investment is being attracted into the various precincts being established: arts, justice, health, innovation, retail, inner city residential development connected by a green frame. Strong public feedback has advocated green spaces, accessibility and sustainability. An alliance of contractors, the Stronger Christchurch Infrastructure Rebuild Team, SCIRT, has been established to rebuild the extensively damaged **roads, fresh water, wastewater and storm water networks, costing in the order of \$2B**. The residential rebuild, particularly in eastern Christchurch where land damage issues are greatest, has been slow. Confidence to rebuild was initially low because of on-going seismic activity. It has also been complicated by insurance arrangements; demand on resources: engineering, consenting and trade with consequential quality concerns: and accommodation scarcity both for residents having houses repaired or rebuilt and for out of town workforce. Coping with these issues has seen the need for psycho-social support for many.

Another useful framework for consideration of risk is to avoid, control, transfer, or accept the risk. Avoidance in this context is principally in land planning – don't build on land where there is a significant liquefaction or land stability risk. One of the early decisions following the February Port Hills earthquake was to create a Red Zone where multiple hazard exposure (liquefaction, flooding, tsunami, slope stability, rock roll) made reconstruction of damaged property and infrastructure not viable. The Government made purchase offers to about 7000 homeowners on the flat and 700 in the Port Hills to avoid future risk. Work is also underway to consider a better national natural hazards risk framework to avoid constructing the 'Red Zones' of tomorrow. This would include clear geotechnical investigation requirements at various land use planning stages. Controlling the risk is similar to the issues raised in risk Reduction above. Society accepts the risk for some hazards. Although significant effort is put into understanding rare and extreme hazards such as volcanic activity, tsunami, or meteor strike, they are, to date, not recognised in building controls.

Transferring the risk has been a feature of New Zealand's earthquake planning for many years. A national fund managed by EQC provides first call earthquake insurance for all residential property with fire insurance. This is topped up by private insurance (>\$100k). This has meant that New Zealand has very high insurance coverage, approximately 95% of households are covered for earthquake risk, verses some 13% in California with a similar earthquake hazard. The scale of damage, with some 160,000 houses submitting in excess of 450,000 insurance claims, and multiple nature of events meant that claims were not able to be fully assessed before the next quake. Apportionment of damage to events was important to determine EQC versus private insurer and reinsurer liability. Insurance concepts have been tested and clarified in court rulings. Many issues are yet to be resolved, such as land damage liability, and increased flooding vulnerability from land settlement, both tectonic and liquefaction induced. These factors have resulted in one of the biggest and the most complex insurance and reinsurance event anywhere. (King 2014). There has also been speculation that



the very high earthquake insurance penetration has resulted in buildings being rebuilt rather than repaired.

Resilience

Resilience relates to minimising the effect from whatever might occur, the ability to ‘bounce back’. The sequence has highlighted areas lacking resilience, and rebuilding a city provides opportunities to improve. Experience from previous international earthquakes demonstrated the need for clear technical repair and rebuild guidelines for insurers, homeowners, designers and other parties. While the worst areas were Red Zoned, rebuilding or repairs were still required on liquefaction-prone land or areas of mass movement in the Port Hills. The Building Act and Code did not anticipate such a scenario and supporting documents to support repair and rebuilding were not available. MBIE used expert engineering and remediation specialists, its Engineering Advisory Group, EAG, to provide this. The resulting guidance, now the benchmark for insurers and their Project Management Offices, councils and designers, has been rolled out progressively as data has been analysed and considered, new research results have become available, or new developments have occurred (MBIE 2012). Improving resilience where appropriate, while mindful of costs has been the philosophy behind this work. The same philosophy has also been applied in developing detailed engineering evaluation guidance for earthquake-affected commercial and industrial buildings, and repair of industrial buildings.

Changes to building regulatory requirements were made early on in the sequence to require improved foundations recognising the liquefaction hazard and to increase the seismic hazard factor in Canterbury, increasing the seismic design loading by 35% (Z from 0.22 to 0.30) to recognise an increased hazard in Canterbury over the next few decades (DBH 2011). Intensive investigations were carried out into building failure and recommendations made. (DBH 2012, CERC 2012). A significant work plan has been set for government agencies and professional bodies.

Better understanding of building performance to improve resilience is being progressed by active international collaboration and research. Collaborative international research is considering the performance of reinforced concrete buildings during the sequence and the recommendations made by the Canterbury Earthquake Royal Commission. Some unexpected damage patterns have challenged existing post elastic behaviour assumptions. Recent ground improvement trials in the red zone will provide new solutions to mitigate the effects of liquefaction. Intense geotechnical investigations in Christchurch have been captured in the Canterbury Geotechnical Database with some 30,000 data points (CPT, borehole data, ground water, etc) collected and able to be accessed by the design community. This sharing of information has already produced substantial savings for investigation and design and has changed the way that consulting firms compete. Consideration is now being given to establishing a national database, supporting an NZ wide natural hazards risk framework.



Sustainability

New Zealand's moderate climate and high renewable energy resources (hydro power, wind, geothermal) make improvement to building energy efficiency, often the sustainability focus, less relevant. Approximately 50% of New Zealand's CO₂ emissions are from agriculture, predominantly from dairying, exacerbated over the past decade in Canterbury, with the region going from 28,000 cows in 2000 to 827,000 in 2012. Even these increased carbon emissions will be dwarfed by the embodied carbon required to demolish and rebuild some 1700 CBD buildings. Christchurch, established from the early nineteenth century, was built largely on a swamp. Planning laws have allowed suburban expansion without understanding the hazards. Waste and hazardous waste disposal from city and suburban demolition is costly and contentious. However, the rebuild does provide the opportunity to build back in a more resilient and sustainable way. Initiatives to improve thermal insulation when repairing houses are occurring, not without some resistance because of concern about affecting overall rebuild timelines and betterment, not being the responsibility of insurers. New houses and buildings will be required to be built to more recent higher standards. District plan changes are being made to restrict building in hazard-prone areas. Adaptation measures include recognition of sea level rise affecting flood levels, resulting in minimum floor levels to be raised in flood-prone areas. Pre-earthquake central Christchurch had significant planning issues. There was too much unused poor quality building space and had low numbers of people resident. It wasn't seen as a thriving, dynamic centre. New plans with emphasis on green spaces, public transport and mixed residential, recreation and business hubs have the potential to enhance the economic, social and environmental sustainability.

Conclusions

Many lessons from Canterbury will benefit the rest of New Zealand to improve overall resilience and sustainability. However future earthquakes elsewhere will present different issues (landslides, logistics and access, lifelines) so there will always be a need to be flexible and pro-active, to consider the "what-if" scenarios, monitor best international practice and have appropriate enabling legislation. Improved resilience will improve economic sustainability. Clearly New Zealand cannot afford 20% GDP shocks often. Investment confidence would plummet and international reinsurance would likely be unavailable. Similarly social cohesion and environmental sustainability are linked to improving the resilience of the built environment. This is balanced by the opportunity for renewal.

Canterbury has demonstrated the importance of collaboration, between engineers, architects, planners, seismologists, regulators, and politicians. Even between structural and geotechnical engineers. With such interdisciplinary communication, hazards can be better recognised and mitigated, building performance can be improved, cities can be more liveable, our environment better protected. Regulators need to be openly thinking about such possibilities when designing regulatory schemes, being pro-active but flexible as different issues will arise. Seeking and being open to international expertise and collaboration has been important in Canterbury. Rebuilding for those affected is a priority in the recovery process. However, equally important are the lessons, whether they be an improved understanding of building



performance in earthquakes or from past mistakes. On behalf of all those who perished and their families, we can't waste the opportunity to learn, to reduce the risk associated with future events, and to improve the resilience and sustainability of our towns and cities.

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Session 93:

Are current building regulations adequately advancing sustainable buildings? If not, what is missing, and how should they be changed? (II)

Chairperson:

Dodds, Bill

Scottish Government. Scotland



Are current building regulations adequately advancing sustainable buildings? If not, what is missing, and how should they be changed? (Part II)

Chairman: Dodds, Bill, Scottish Government. Scotland

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Abstract: *This session brings together policy-makers, government officials, researchers and others to present perspectives on how innovation in building regulation and control, such as performance-based approaches, are currently being used to advance sustainability concepts in buildings, whether we are doing enough, and where and how we might see further innovation in the coming years. In this grouping of session papers, representatives of the Inter-jurisdictional Regulatory Collaboration Committee (IRCC) and the International Council for Research and Innovation in Building and Construction (CIB) Task Group 79 discuss a range of policies implemented in their countries and/or the focus of research and development in their respective countries. Related papers can be found in the corresponding set of session papers (Are current building regulations adequately advancing sustainable buildings? If not, what is missing, and how should they be changed? (Part II)).*

Keywords: *building regulatory systems, building control, performance-based, sustainability, climate change, resiliency*



Impact of energy efficiency goals on systems of building regulations and control

Note: This paper has been peer reviewed by the World SB14 Barcelona Scientific Committee

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H.J. VISSCHER and F.M. MEIJER, OTB Research for the Built Environment, Faculty of Architecture and the Built Environment, Delft University of Technology, Delft, The Netherlands (h.j.visscher@tudelft.nl) – *Impact of energy efficiency goals on systems of building regulations and control*

Abstract: *Considerations of climate change, but also other political and economic reasons urge for the reduction of use of fossil fuels and the minimization of environmental impact by the built environment. The energy saving potential of the building stock is large and considered to be the most cost efficient sector to contribute to the CO₂ reduction ambitions. Goals set by the European Union are to build net zero energy buildings in 2020 and to reach a neutral energy building stock by 2050. As long as the price of renewable energy is still not competitive with fossil energy, the energy saving goals can only be reached by strict governmental policies. In Europe the Energy Performance of Buildings Directive and the Energy Efficiency Directive are driving forces for EU Member States to develop and strengthen energy performance regulations for new buildings and energy performance certificates (labels) for the building stock. The goal of this paper is to analyse the consequences of these developments on the systems of building regulations and control. It appears that, apart from adding new subjects, these new and very ambitious goals require systemic innovations in the regulatory systems. The current structures and approaches might not be adequate to deal with the new challenges. This is concluded from ongoing research that shows that aims of regulations in general and energy saving goals in particular, are hardly realized in practice.*

Keywords: *Energy Saving, Energy Performance, Building Stock, Building Regulations, Building Control*

Introduction

Climate change mitigation is maybe the most important driver for the ambitions to reduce the use of fossil fuels. There are also other reasons for implementing energy efficiency policies in the EU and its Member States. These include the wish to diminish the dependency on fuel imports, the increasing costs and the fact that fuel resources are limited. The European building sector is responsible for about 40% of the total primary energy consumption. To reduce this share, the European Commission (EC) has introduced the Energy Performance of Buildings Directive, the EPBD (2010/31/EC) and more recently the Energy Efficiency Directive (EED – 2012/27/EU). These frameworks require Member States to develop energy performance requirements for new buildings, a system of energy performance certificates for all buildings and policy programmes that support actions to reach the goals like building only ‘Nearly Zero Energy Buildings (NZEB)’ by 2020 and realizing an almost carbon neutral building stock by 2050. Formulating ambitions and sharpening regulations are relatively easy to do. Technical solutions are currently available to realise the NZEB standard in building



projects and more and more projects of this kind are being build. There is quite some evidence however that the mainstream of building processes does not lead to the pre-defined quality or that the instruments are not adequate to reach the goal. What is perhaps even more important in this respect is that focus predominantly should be directed on the existing building stock. About 75% of the buildings that will make up the housing stock in 2050 have already been built today. This paper sketches the main developments in the field of building regulatory systems and building practice in the context of the increasing energy saving target, both for new as well as for existing dwellings. The main question addressed is whether the current regulations and forms of building control are adequate to realize the energy saving goals set by the EU and its Member States.

Developments in building regulatory systems

Building regulations are continuously the subject of debate. On the one hand regulations should be minimized to reduce the administrative burden on citizens and businesses. On the other hand new quality themes emerge that require regulatory intervention. Energy and climate change is such a theme. The European Union and its Member States have developed regulations and enforcements schemes that ensure very energy efficient new buildings and instruments that stimulate the improvement of the existing stock. Although the general development in European countries leads to less government intervention in the building sector, in the field of energy efficiency the number of regulations increases and become more stringent. Currently in the Netherlands the debate is very alive. The desire for deregulation is leading to the opinion that greater emphasis should be placed on the responsibility of property owners, which could lead to less governmental intervention. However, the existing forms of quality control for private actors in the Dutch building industry appear to be not adequate enough. Incidents occur and the physical quality sometimes falls short of the expectations. As the CO₂ reduction and energy efficiency targets increase, stronger regulations and accurate building control become a priority.

The realisation of required energy performances in practice

In 1995 energy performance regulations for space heat and cooling of newly built constructions were introduced in the Netherlands. It consist of a standard for the calculation method which is called the Energy Performance Norm. The norm results in a non-dimensional figure called the Energy Performance Coefficient (EPC*). Every few years the level of this Energy Performance Coefficient was decreased, representing a lower energy use demand for heating. In 2020 new dwellings must be energy neutral. Since the introduction only a few studies were conducted to assess the effect of the regulations on the actual energy use. The samples were of limited size as well. Two studies found no statistical correlation between the energy performance coefficient level and the actual energy use per dwelling or per square meter. Analysis of the WoON (2009) survey, (that was carried out on behalf of the Dutch government in 2006 containing a representative sample of 5000 dwellings), also found no correlation between the different levels of the energy performance coefficient and the actual

energy use per dwelling and per square meter (see Figure 1). Guerra Santin (2009, 2010) compared the actual and expected energy consumptions for 313 Dutch dwellings, built after 1996. The method included an analysis of the original EPC* calculations that were submitted to the municipality as part of the building permit application, a detailed questionnaire and some day-to-day diary's. These combined approaches generated very detailed and accurate data of the (intended) physical quality of the dwellings and installations, about the actual energy use (from the energy bills) and of the households and their behaviour. The dwellings were categorised according to their EPC*.

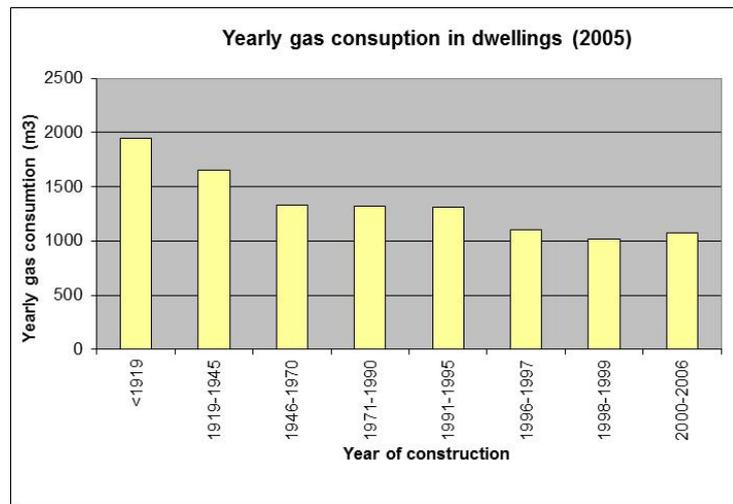


Figure 1 Yearly gas consumption in m³ in Dutch dwellings (WoON 2009) (note: non linear proportions)

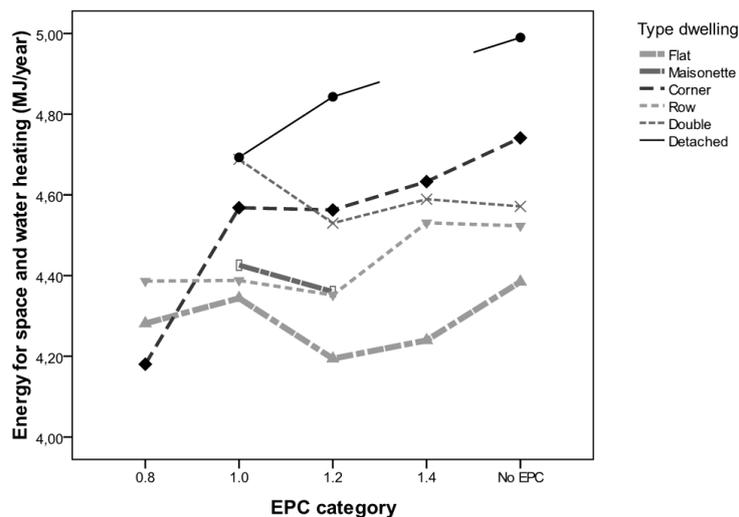


Figure 2 Actual energy use in relation the Energy Performance Coefficient per Type of dwelling (Guerra Santin, 2009)



In energy inefficient buildings with a high EPC*, actual energy consumption for heating was almost twice lower than expected. Whereas in buildings with a high energy efficiency, the expected and actual energy use coincided much better. Due to the relatively small sample size, the differences between the actual heating energy of buildings with different EPC* values were insignificant. Nonetheless the average consumption was consistently lower in buildings with lower EPC*. Guerra Santin found that building characteristics (including heating and ventilation installations) were responsible for 19% to 23% of the variation in energy used in the recently built building stock. Household characteristics and occupant behaviour seemed to be responsible for 3% to 15% of the total variance. On the basis of our study and other literature studies one can state that building characteristics, household characteristics and occupant behaviour altogether are responsible for at most 38% of the variation on energy consumption of dwellings built after 1995. Therefore at least 62% of the variation in energy use was unexplained by theoretical performance and behaviour and must be caused by other reasons.

There are indications that some of the explanation could be related to the fact that buildings are constructed differently in practice than is described in the design documents and that HVAC services operate in very different conditions than assumed beforehand. Nieman (2007) showed that in a sample of 154 dwellings, 25% did not meet the energy performance requirements because of incorrect calculations. Nevertheless the building permit was issued. In 50% of the dwellings, the realization was not in accordance with the design. These results match with findings about inadequate performance of both building control as the building industry in the Netherlands and other countries (Meijer e.a. 2002, 2006, 2008). Taking into account the above findings, one can have some doubts if a further tightening of the energy performance regulations will lead to a better energy performance in practice. Perhaps there are other and more efficient solutions to decrease the energy consumption of newly built dwellings in practice. Important ingredients of the solution are: ensuring that appliances and installation are correctly installed, monitoring the calculated performances in practice; enlarging the know-how and skills of building professionals and putting in place an effective and efficient building control and enforcement process.

Policies and instruments for energy reduction in existing dwellings

It is relatively easier to apply energy saving measures in newly built buildings. However the largest energy saving potential is in the existing building stock. On average new dwellings add less than 1 per cent per year to the housing stock. The most important policy tool required by the EPBD in the European Member States is the issuing of Energy Performance Certificates (or EPC's). The EPC gives an indication of the energy demand necessary to realise a certain average temperature in the building and depends on physical characteristics of the building. The EPC indicates the energy demand for heating and cooling. The certificate has no mandatory implications in the sense that owners could be forced to improve their buildings to certain levels. Nonetheless it could be a crucial instrument for benchmarking and formulating policy goals. Building owners in all Member States have to produce an

EPC for a building at the moment it is sold or re-rented. This is not yet current practice everywhere, mostly due to lacking of enforcement. This especially applies to the private housing stock. In the Netherlands however, the complete social housing stock is labelled with an EPC. The social sector in the Netherlands is still relatively large (35%) and well organised. For the social housing stock the EPC's are collected in a database. With this database the progress of the renovation practices can be monitored. Besides that the relation between the EPC's (with the calculated energy use) and the actual energy use can be studied. A few years ago the sector formulated ambitious programmes, but these have been scaled down because of several reasons. The economic crises reduced the financial position of the housing associations. The housing market also dramatically slowed down which also affected the funding for renovations because this largely depends on the sales of property. Also it proved to be difficult to get approval of tenants for renovations that require an increase of the rents (70% of the tenants have to agree). It is hard to assure the saving of energy costs resulting of the improvement of the dwellings. All in all the progress of renovations and energy upgrading measures stays far behind expectations and formulated ambitions in 2008 when most of the policies, covenants and improvement programmes were set up.

Besides the physical characteristics, the actual energy use is largely influenced by the use and behaviour of the tenants. Some preliminary figures demonstrate the difficulty in 'forcing' reduced energy use by improvements of dwellings. The dwellings with the worst EPC (G) in practise use far less energy as expected, while the most advanced dwellings (A) use much more. This is probably due to a combination of the rebound effect and an increase in comfort level of the dwellings (Majcen et al 2013a, 2013b) and underperformance of the buildings and installations. Figure 3 shows the actual and theoretical gas consumption per dwelling per EPC. In the homeowner sector the issuing of EPC's stay yet far behind the expectations. This means that the intended purposes are not reached. When EPC's become common practice they could affect the sales price. There is no enforcement system in place to guarantee that only buildings with an EPC can be traded on the housing market.

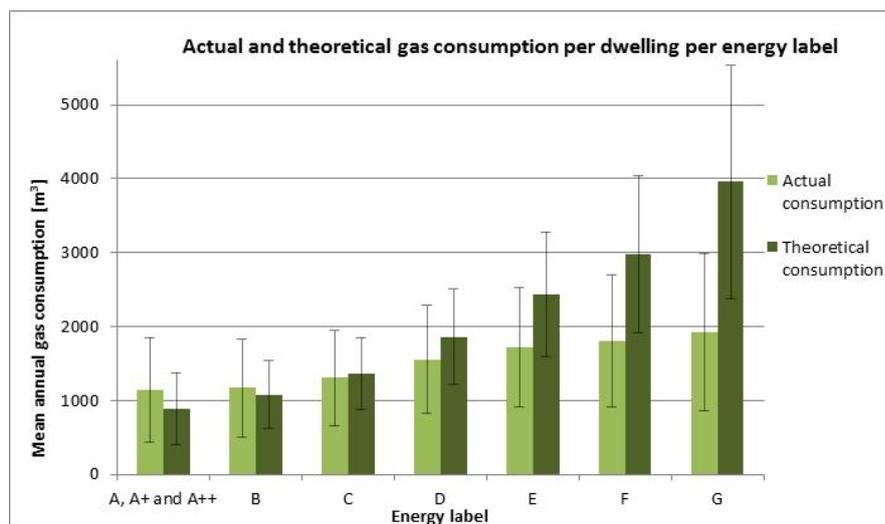


Figure 3 Actual and theoretical gas consumption in Dutch dwellings (Majcen et al., 2013a)



Impact on the systems of building regulations and control

Without any doubt there is a necessity to drastically reduce the use of fossil-fuel energy sources by reducing the demand for energy and switching from fossil to renewable sources. Buildings account for 40% of Europe's energy consumption and three-quarters of the floor area of the building stock is residential. The targets are clear and the technical solutions are available. Severe insulation and product innovations can reduce the energy demand for heating and cooling for a large part. The remaining energy demand can be delivered by renewables like sunlight and heat, district heating, heat pumps, etc. The remaining electricity demand for appliances can in the first place be reduced by further product innovation and then be provided by photovoltaic panels. There are no reasons not to apply these solutions in new buildings at a large scale on the short term. Evaluations of the current practice show however that there is a lot to be gained here. To improve this situation it has to be assured that constructions and installations are installed properly and in such way that they are not vulnerable for unpredictable or misuse by the occupants. This will set demands on both the construction industry as on the control and enforcement process (and the parties responsible).

Better quality control during the whole process is absolutely essential. It is quite feasible to charge the building professionals with this task. Our international comparative research into building regulatory systems shows a tendency to put more emphasis on the responsibilities of owners and private parties (instead of local authorities) to control and ensure the minimum quality of construction works. For a successful transition towards energy neutral construction stricter demands must be set on the knowledge and skills of these building professionals (designers, engineers, installers, constructors, etc.). They will have to use new techniques and improve the quality and accuracy of the work. This means that they not only will have to improve their operating procedures but also have to implement performance guarantees. Owners and users will require quality guarantees from the designers, installers and constructors. Certification and accreditation of parties, processes and products will become more important for building processes in general. For the realization of high energy performance standards, a reliable quality assurance system will be very important. In most countries that have some experiences with passive houses some form of performance guarantee and associated quality assurance scheme exists. It is important to study these examples.

For new constructions a successful transition lies easily within the bounds of the possible. The existing building stock forms a far greater challenge. The potential energy savings are far bigger, but the barriers to overcome are also higher. As stated before almost three quarters of the future housing stock (2050) has already been built. Studies show however that it is hard to increase the rate and depth of energy renovations of the existing stock. Actual energy (and financial) savings in renovated dwellings stay behind expectations because of rebound effects. There are important barriers. Many owners believe that the benefits of the measures do not



outweigh the costs. Besides that, the cost of improving the energy performance of a dwelling does not (proportionally) increase the value of the dwelling.

We are faced with the difficult task to increase the energy renovation pace. The question is how this process can be accelerated. Maybe there is still room for further smart product development. Innovative products that contribute massively to the reduction of energy demand, that are cheap, easy to apply and to handle by occupants and users. The fast decrease of the price of PV cells is promising.

Climate change and the related demands on buildings will have a profound impact on the design of building regulatory systems. The past few years OTB – Research for the Built Environment has been involved in studying alternative visions on building regulatory systems in international comparative projects. What we see in most countries are discussions (or sometimes even concrete developments) where the balance slowly shifts from:

- Command and control regulations towards more economic incentive based policies;
- Public control and enforcement towards a more dominant role of private parties/building professionals (together with the materialisation of far more robust and reliable certification and accreditation schemes);
- A strong focus on control of the design to monitoring of the building process and testing of the quality of the final building and post occupancy monitoring.

At the same time the role of regulations for existing buildings come under scrutiny and from a range of stakeholders attempts are undertaken to search for solutions. Instant solutions are not easy to give. None the less along the most probable solutions will move in the directions sketched above.

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Perspective of the Building Sustainability Regulatory Evolution in Spain: From Prescription to Performance

Note: This paper has been peer reviewed by the World SB14 Barcelona Scientific Committee

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Abstract: *The very last few years have seen a huge change in the regulations affecting building sustainability in Spain and the present offers a challenging panorama as the amount of effort and money involved in this legal transition asks for a critical evaluation in terms of effectiveness. The first results of the implementation of the 1999 Building Act and the 2006 Code have coincided in time with a deep economic crisis affecting specially the building activity in the country, therefore not allowing an easy evaluation of their impact. In addition, the EU has set very ambitious objectives in this subject that urge an optimization of the requirements, methods and tools required to face the problem. The efficiency of some of the requirements in the Code, that were purely prescriptive, has been questioned by practitioners and code officials. The regulations and the practice are moving quickly from prescription to performance.*

Key words: *Sustainability, regulatory evolution, requirements, prescription, performance, verification methods, verification tools*

1. Introduction. Global perspective

Until early in this century, by 2006, Spain did not have a unified single national Building Code. Different regulations formed an open framework based in a prescriptive approach. There were specific regulations for buildings, named Basic Building Standards (“*Normas Básicas de la Edificación*”, NBEs), which formed a series of separate regulations dealing with structural, noise protection, thermal insulation, energy performance, protection against moisture, and fire safety requirements. NBEs were approved through royal decrees by the Government.

In 1999, the new Building Act established a new building regulatory system. The Act aims to achieve a better quality in building, so provisions determining the minimum quality levels of buildings, the professional competencies and responsibilities, and the liabilities and insurance requirements were all set out in the Act. In this way the Act proposes, in terms of objectives, the minimum “*basic building requirements*” regarding functionality, safety and habitability, which includes requirements on accessibility, structural and fire safety, safety in use, hygiene, health and environment protection, protection against noise and energy and thermal



insulation. These general objectives just set and briefly defined in the Act [1], needed to be developed by the Government in a technical Building Code (“*Código Técnico de la Edificación*”, TBC) referred as “Code” in the following [2]. The main objective of the Code was to supersede the old and obsolete framework by getting a modern, simple, and effective set of building regulations unified in a single Code comparable to the most advanced in the world. The Performance-Based approach, achieved in many developed countries was taken into account as much as possible, and served to arrange the Code around the so-called Nordic five-level hierarchy according with the IRCC guidance. Therefore, the Code initiates the evolution of the Spanish regulations from prescriptive to performance.

The intention of the regulator was to draft the Code in two parts: A first one, that includes the Code functional requirements and a second part, composed by the quantification of the requirements and the verification methods which include the official methods of fulfilment. The new Code had, as old NBEs had too, an “equivalence clause,” which allows the designer (architect or engineer) and the director of the works to adopt solutions differing from those in the regulations, provided they prove by other means the fulfilment of the objectives in that regulation. The clause is aimed to allow and encourage innovation, and also consider the importance of the Spanish professional’s competence in the construction field.

2. Current regulations in Spain

The Code was approved in 2006 by Royal Decree 314/2006, of 17th March, as the new building regulatory framework that establishes performance-based basic requirements to be met by buildings, in terms of the essential requirements. The Code was intended to be as a well-organized normative framework and seeks to facilitate their application and fulfilment, in harmony with European regulations. The Code coexists with other technical regulations, such as the one on concrete structures (that includes both building and civil engineering), the seismic regulations, those on installations like heating and cooling facilities, gas, electrical equipment, etc. Crossed references are in both worlds.

2.1. The Building Code and Sustainability

As said before, in concept, the Code was developed in two parts. The first one includes general provisions and a detailed expression (in qualitative or quantitative terms) of the basic requirements laid down in the Act, and the second part deals with the fourth and fifth levels in the Nordic arrangement: methods of verification or compliance and acceptable solutions. The requirements of the Code shall be considered as minimal, without prejudice to more stringent values which may be established by the competent authorities and which contribute to sustainability, taking account of the actual characteristics of their local environment, but in fact, actually this possibility rarely exists. Regarding the sustainability issues, the Code includes some requirements that contribute in general to protect the environment and some to limit the use of energy which indirectly contributes to lower CO₂ emissions to the environment. But the environmental performance of a building is just only one aspect of its sustainability. The social and economic aspects of the building are also matters that should be



taken into account as part of any sustainability assessment. Furthermore it is necessary to keep in mind that the Code applies exclusively to the building and its nearby environment.

The first environmental objective was to ensure a ‘rational use of the energy’ needed for the building to be run properly. This was to be accomplished through compliance with five requirements expressed in a performance-base: limitation of energy demand, maximum efficiency of heating and cooling systems, energy efficiency of lighting systems, a minimum solar contribution for domestic hot water, and a minimum photovoltaic contribution for electric energy. These objectives were stated in the performance approach as much as it could. In addition other requirements somehow related with sustainability were stated within other specific health protection basic requirements, such as disposal of waste, air quality, water supply, drainage of wastewater, and also protection against noise.

2.2. Updating Sustainability aspects of the Code

The Energy Performance of Buildings Directive [3] published in 2002, required all EU countries to enhance their energy regulations and to introduce energy certification schemes for new and existing buildings. With the adoption of the recast EPBD in 2010 [4], EU Member States faced new challenges, like going towards nearly-zero energy buildings by 2020 (2018 in the case of Public buildings). The updated Code needed therefore to rise the 2006 energy standards (for both new and existing buildings) to higher levels seeking to meet the ‘nearly zero-energy concept’ through increased energy efficiency of the building envelope and systems, and additionally with an increase of the already required contribution of renewable energy. This made necessary an updating of the Code Basic Document on Energy Performance (DB HE) towards a substantial reduction of the energy consumption in new buildings, approaching the EU directive with cost-optimal requirements and asking adequacy to the new requirements when retrofitting existing buildings.

By June 2013 the Code scope included in its Part I was amended by the new Act 8/2013 on Rehabilitation, Renovation and Urban Regeneration [5] which amended also the Building Act 1999. Both amendments are aimed to get a better application of both Act and Code in those interventions performed on existing buildings. New criteria on how the Code provisions must be taken into account in any intervention on existing buildings have been set. They are the principles of ‘not worsening’, ‘proportionality’ and ‘flexibility’. The classifications of types of intervention in building that are subject to regulatory enforcement have been also clarified in three categories: “reform works”, “changes of use” and “extension of buildings”. As said, the updating of the energy part of the Code is due mainly to the need to transpose part of the European Directive 2010/31/UE on energy efficiency in buildings, EPBD [6], but as well as the need to regularly update the Code, accordingly to the evolution of technology and demands of society, as it is claimed by the Building Act.

The new energy Code presents a remarkable increase in the level of energy efficiency of buildings with respect to the levels established in 2006, focusing towards the ambitious target

of having 'nearly zero energy buildings, nZEB' by 2020. Some of the most significant changes are that the new performance requirements affect both the new construction and the interventions in existing buildings and that a new Code Section HE 0 has been introduced to incorporate a new requirement to limit the energy consumption depending on the climate zone and building use. Besides that a new draft modification in the Code which is still pending affects a lot of its parts. The main changes of the update are those focused to better regulate the fulfilment of the Code in rehabilitation of existing building. The main reason for the review is that the current application of the current Code in existing buildings was having quite complexity and has generated many doubts and questions among both professionals and municipal building controllers in charge of issuing building permits. The new set of criteria for the application of the Code in existing buildings has been drafted in order to achieve the maximum possible approach to an acceptable level of performance. The challenge that has been found is to establish how much the level of performance required for a new building can be reduced to an acceptable level in an existing building and whether it is possible to determine different levels of performance in every case. The classic structure of the Code upon the Nordic five-level hierarchy is being completed in Spain with many supporting documents that are not strictly part to the Code which are drafted to facilitate its use. These voluntary supporting documents permit to fulfil the requirements with more freedom by using the performance approach. An image of the current Spanish building regulatory framework is shown in Fig 1.

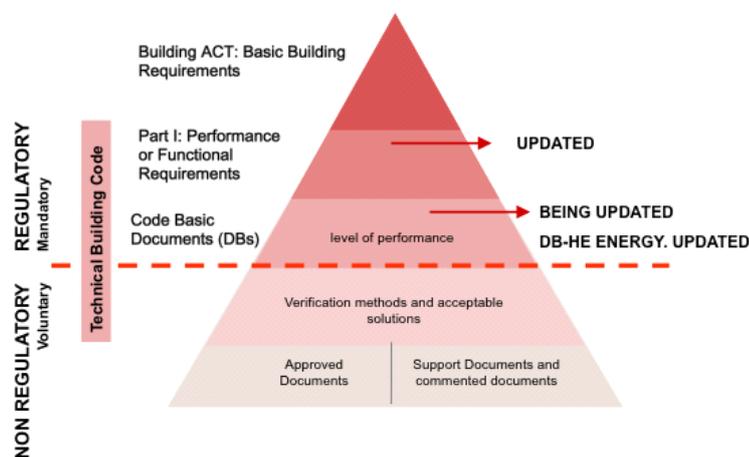


Fig 1. Code Hierarchy scheme

3. Standards about sustainability

In the recent years a set of new standards have been developed related with Sustainability of construction works. CEN/TC 350 is responsible for the development of voluntary horizontal standardized methods for the assessment of the sustainability aspects of new and existing construction works and for standards for the environmental product declaration of construction products. This frame includes environmental performance of buildings, building

life cycle analysis, environmental products declaration and economic and social performance assessment. It is expected that in future the Code will increase sustainability requirements.

4. Future perspective

4.1 Sustainability aspects not considered in the TBC (CTE)

As Sustainability is becoming more and more essentially quantifiable, it makes up a good basis for a performance development. The current Energy Efficiency Certification in Spain [7], even with the problems detected along its development since it was initially introduced in 2007 and completed in the following years, is a good example of establishing performance groups that become evident for the stakeholders and the market. Nevertheless, some important issues regarding Sustainability have not been considered yet by the Code or if so, are not dealt with in a performance way, making very difficult its quantification. Table 1 shows a comparison between the sections contained in some recognized international codes, certification tools and the Spanish Code.

IgCC [8]	GBCe [9]	BREEAM [10]	LEED [11]	TBC (CTE) Requirements Tools	P.		
Sections	Sections	Sections	Rating	Sections	Rating		
<u>Jurisdiccional Requirements and Life Cycle Assessment</u>	<u>(The complete methodology is based on a LCA)</u>	<u>(Life cycle impacts in Materials)</u> <u>(Life cycle cost and service life planning in Management)</u>		<u>(Building life-cycle impact reduction in Material and Resources)</u>			
Site Development and Land Use	Site and Location	Land Use and Ecology	10	Sustainable Sites	10		
Material Resource Conservation and Efficiency	Natural Resources	Materials	12	Material Resources	13	SI-1, 2 HS1	
Energy Conservation and CO ₂ e emission reduction	Energy and Atmosphere	Energy	30	Energy and Atmosphere	33	HE-0, 1, 2, 3, 4, 5 LIDER CALENER CE3 CE3X CERMA	X
Water Resource Conservation, Quality and Efficiency	Natural Resources	Water	9	Water efficiency	11	HS-4, 5	
Indoor Environmental Quality and Comfort	Indoor Environmental Quality	Health and wellbeing	10	Indoor environmental quality	16	HS-1, 2, 3, 4, 5 HR GUIA APLICACIÓN DB HR	X
Commissioning, Operation and Maintenance	Service Quality	Management	22			All	
Existing Buildings	X					Part 1	
Existing Building Site Development							
	Social and Economic Aspects						
	Design Quality						
	Innovation	Innovation	10	Innovation	6		
		Waste	7			HS-2	

		Pollution	13			HE-2 HR HS3	
		Transport	9	Location and transportation	16		
				Regional priority	4		
				Integrative process	1		
		TOTAL	130		110		

Table 1. Comparison between different documents and the requirements in the Spanish TBC. An "X" in the last column indicates the existence of a performance frame at the moment

Some of the sections rated in these documents may not be directly considered by the Code, because they exceed their scale or are under the jurisdiction of local or regional governments. This is the case of transportation, regional development or the social and economic aspects. Others, like innovation or design quality, unless interesting, are difficult to regulate from a TBC perspective.

4.2 Sustainability aspects to be considered or changed in the Code

There is no much in the Code about materials and resources in addition to their proper selection to meet the technical standards. The use of a percentage of recycled or local building materials is not established and there is no a requirement for a life cycle assessment. Energy efficiency represents probably the most developed aspect as the last Code modification, in September 2013, has introduced a limitation in the not renewable primary energy consumption [12] for every climate zone in the country. This is obviously tied with the Energy Efficiency Certification, and several software tools have been developed for the purpose. Nevertheless some improvements may be done in the regulation of renewable energy systems to allow more flexibility. At this moment a percentage of hot water energy usage needs to be supplied by onsite solar heating equipment and solar photovoltaic systems are mandatory in some non-residential large buildings. The diversity in the Spanish climate conditions makes inefficient the fulfilment of some of the percentages required in some parts of the geography and a more flexible use of all these renewable resources including wind or geothermal systems and some heat pumps. It is proposed that only a minimum percentage of renewable energy shall be demanded, without a previous determination of the system.

Water is probably the less regulated aspect at this moment, especially if we consider its scarcity in many Spanish regions and the increasing demand of water. The requirements in the 2006 Code were too simple, probably a continuity of the former ones, and haven't been modified since then. On the one hand there is a need to reduce consumption. The water supply requirements, which demand separately hot and cold water minimum flows, ask for a total rate in the fixtures approximately double than the ones considered in the 'International Green Construction Code', IgCC. In addition there is only a demand of flowing reducing devices in public buildings. On the other hand there is a need to enhance reuse. There is a need for a clear definition of the different kinds of water in the buildings, specifying their possible reuse



process. It is especially important to define their origin and their final use. It is suggested that a definition of gray water doesn't include flows from kitchen sinks or dishwashers in addition to water closers and urinals.

The indoor environmental quality is regulated by the Code sections HS3 and HR, but also by a different technical regulation on thermal installations in buildings, RITE 2007. Unless this regulation considers different air quality levels, the first one does not. The Code regulates the air quality only in residential buildings and car parks allowing both mechanical and hybrid systems for housing. The hybrid system, which in fact is a combination of natural and mechanical ventilation, requires intake air openings for a 0.7-08 air changes per hour for a medium size house and therefore, in addition to other infiltrations, represents a challenge for energy conservation in some regions. Mechanical systems for intake and extraction air with a heat recovery device have proved the best solution for the purpose. Other strategies, like the activation of the systems under occupant detection can combine adequate air renovation with reduced energy consumption.

In addition there is no a specific regulation for banned materials but it is suggested that some toxic or hazard materials could be listed, taking into account the relevant EU provisions in this field. Noise is considered a wellbeing requirement and unless a prescriptive procedure is established is required to be completed with post construction testing. The only aspect of waste disposal considered by the Code is the establishment of a specific space to collect ordinary waste in residential buildings, allowing in other uses a similar procedure. Some air pollution aspects, like materials toxicity and the emissions from building fires could be considered.

The existing building stock represents a real challenge at this moment. This is due to the poor performance of many of the existing buildings, built under none or very low standards and the necessity of renew the city centres. The recent Act 8/2013 of Rehabilitation, Regeneration and Urban Renovation has modified the Code to allow some flexibility in its fulfilment, but there is still a big lack of clear benchmarks for a clear interpretation. A good clarification and classification of the works is needed to allow both practitioners and code officials to reach agreement. The use of different alteration levels, as the ones considered in the International Existing Building Code IEBC [13], could be a good solution to face the problem. Some evaluation tools regarding the previous and reached building performance for different requirements like energy, health or safety, and the involving costs, could be a good help for decision. This will allow certain asymmetry in the works but ensuring some minimum performance levels in aspects that don't represent the main concern.

5. Conclusions

- The Spanish Code, CTE, does not consider, so far all aspects regarding Sustainability, if it is compared with some recognized Green Codes or Sustainability Evaluation Tools.



- Unless a big effort has been done in Energy Efficiency, under the EU regulations, other important aspects remain as were initially considered in 2006 and are essentially prescriptive. Some of them, especially regarding materials, water and indoor environmental quality, as those included in section HS1 need to be revised and changed towards a better performance characterization.
- Although there are some other aspects of sustainability that legally will not be enforced directly by the Code, it is important to recognize the existence and availability of some official tools on Sustainable characterization or Life Cycle Assessment.
- The improvement of the existing buildings stock represents the biggest challenge, due to its big number and their bad performance.

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- [5] Act 8/2013 of Rehabilitation, Renovation and Urban Regeneration
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- [9] GBCe, Verde NE Equipamiento, 2012
- [10] BREEAM International New Construction Technical Manual, 2013
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- [12] BOE 12/09/2013
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Reviewing challenges between the need for government-subsidized housing in South Africa and the sustainability requirements of the National Building Regulations.

Note: This paper has been peer reviewed by the World SB14 Barcelona Scientific Committee

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Jacques LAUBSCHER, Department of Architecture, Faculty of Engineering and the Built Environment, Tshwane University of Technology, South Africa (laubscherj@tut.ac.za) – *Reviewing challenges between the need for government-subsidised housing in South Africa and the sustainability requirements of the National Building Regulations*

Abstract: *In Sub-Saharan Africa, building operations are estimated to be responsible for 56% of energy used. Between 1994 and 2014, the South African government built approximately 3.6 million homes, accommodating more than 11 million people. Despite this effort, official statements claim that 23% of South African population is currently living in an informal dwelling. In an effort to reduce costs, the erection of government-subsidized housing is partially exempt from the requirement of the National Building Regulations. This paper reviews the challenges between the need for government-subsidized housing in South Africa, the National Building Regulations and a passive design approach.*

Keywords: *South Africa, National Building Regulations, government subsidized housing, low cost housing, passive design*

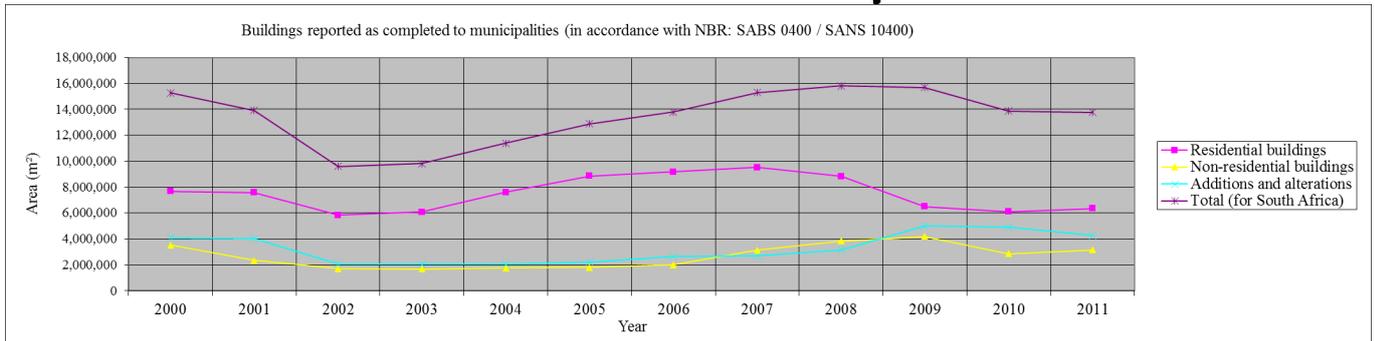
Introduction

The South African built environment could be divided into two specific parts, namely the formal and the informal sector. Unavoidably, this division is mostly based on economic standing. Housing forms the largest part of the informal segment. The aggregated per capita income of a household mostly determines whether a family is housed in a formal or informal structure. However, the formal and informal housing categories remain inextricably linked.

Current status quo

For the period 2000 – 2011, the government agency Statistics South Africa (Stats SA) reports the total completed building projects in South Africa at 161,058,295 m² [1]. The total area constructed in South Africa for the respective years is summarized in Figure 1:

Figure 1: Building reported as completed to South African Municipalities (2000 – 2011)

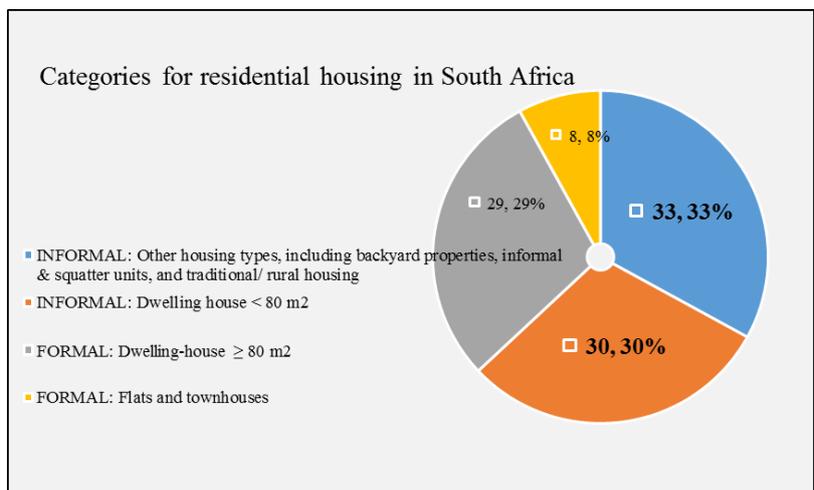


Three different categories are used by Stats SA to classify the built environment. During the period 2000 – 2011, the completed building area in South Africa for the respective categories are the following: [1]:

- Residential buildings: 90,050,494 m²
- Non-residential buildings: 31,936,026 m²
- Additions and alterations: 39,071,775 m²

The residential component is the largest contributor to the South African built environment. According to the definitions used by Stats SA, the informal component of residential buildings comprises both traditional- and informal dwellings. Using the context of its location, the informal dwelling is further divided into the Traditional dwelling/hut/structure made of traditional materials; the Informal dwelling in backyard; and the informal dwelling not in backyard. The extent of informal housing is more than 63% of the residential building category [2]. The various contributors to the houses in South Africa are summarized in Figure 2:

Figure 2: The sectoral contribution to residential buildings

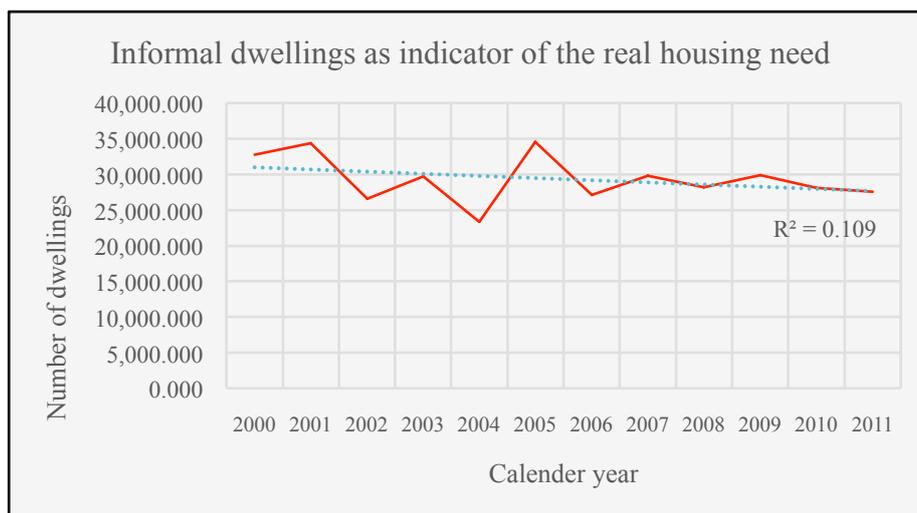


Real world problem

According to official statements, the South African government built 3 584 689 homes [3], accommodating more than 11 million people during the period 1994 - 2014. On 22 May 2013, the then Human Settlements Minister Tokyo Sexwale tabled a R28.1 billion budget before Parliament. According to Minister Sexwale, the “2013/14 financial year allocation signified the Government’s determination to eradicate the problem of homelessness in the country” [4]. At the same occasion, the housing “backlog of 2,1 million houses for 8 to 10 million people,” was highlighted [4]. Using the lowest subsidy and official backlog statistics, the current value of this shortage is an estimated cost of R232 billion (R232,987,755,000.00) or €16,5 billion (€16,514,405,062.16).

The number of informal dwellings is considerably more than the official housing backlog. There could be various possible reasons for the phenomenon of informal housing in SA. Nonetheless, it could be argued that the use of an informal structure (as a dwelling) should rather serve as an indication of the real housing need. When using information from Stats SA, the changing population statistics indicate an increase in urbanization and emphasize the challenges surrounding the housing backlog. Using the available data on informal dwellings from Stats SA, while excluding the number of traditional dwellings¹, the real housing need in South Africa is estimated to be more than 25 million units. In Figure 3, the number of informal dwellings are presented as the actual housing need [1].

Figure 3: The total number of informal dwellings for the period 2000 – 2011



Current subsidy for government subsidized housing

¹ A traditional dwelling being a house that is constructed using traditional building materials.

There are various different categories of government-subsidized housing ranging in size from 40 m² – 70 m². The 40 m² *Stand Alone Residential Dwelling* is the most often used prototype. The current total *Individual Housing Subsidy Quantum* for the 40-m² dwelling is R160,573.00. This total is divided as follows [5]:

- R110,947.00 (€7,864.03) construction cost of the house,
- R43,626.00 (€3,092.25) for the services cost, and
- R6,000.00 (€425.29) for the raw land cost.

Table 1: Detailed cost breakdown of government subsidy for a 40 m² dwelling [5]

DETAILED COST BREAKDOWN OF THE STANDARD 40 m² HOUSE FOR PERSONS EARNING BETWEEN R0.00 - R3 500 /month or €0.00 - €248.08 FINANCED BY THE NATIONAL HOUSING PROGRAMME of SOUTH AFRICA		
(Implementation date: 14 April 201		
Cost element	Cost (ZAR)	Cost (€)*
Earthworks	R 6,707.48	€ 475.43
Concrete, Formwork & Reinforcement	R 10,780.37	€ 764.12
Brickwork	R 15,528.48	€ 1,100.67
Roof Structure	R 8,832.44	€ 626.05
Ceiling and insulation	R 7,311.82	€ 518.27
Windows [Standard]	R 4,092.34	€ 290.07
Windows: Special LowE clear and opaque glass	R 3,991.19	€ 282.90
Doors and Frames	R 6,558.00	€ 464.84
Finishing and paintwork	R 10,637.98	€ 754.03
Electrical	R 9,958.40	€ 705.86
Plumbing and toilet	R 9,976.38	€ 707.14
Total (Building costs)	R 94,374.88	€ 6,689.39
P&G	R 8,578.67	€ 608.06
Project manager	R 3,604.00	€ 255.46
Clerk of works	R 3,089.00	€ 218.95
Transfer cost	R 1,000.00	€ 70.88
Beneficiary administration	R 300.00	€ 21.26
Total (Project costs)	R 110,946.55	€ 7,864.00

*Calculated using an exchange rate of R14.11 for €1.00 (23/05/20

The National Building Regulations in South Africa

The National Building Regulations and South African National Standard (SANS 10400) (NBR) state the minimum obligation for the owner of a building. The requirements of the NBR is controlled when a proposed building plan is submitted to the LA for approval. Without the necessary approval, the construction and/or alterations to an existing structure cannot proceed. The NBR introduced in 2011 a new section titled SANS 10400 Part XA- Energy Usage in Buildings. The primary aim of Part XA is to address the spiraling energy



consumption of South African buildings. The challenges with the necessary compliance to the revised requirements of the NBR are generally associated with higher building costs.

Government exemption from the National Building Regulations

The South African Government is one of the major land and building owners, but it remains largely exempt from compliance with the requirements of the NBR. Sections 2(3) and 2(4) of the amended *National Building Regulations and Building Standards Act, 1977* explicitly state that the Government is not obliged to submit plans for approval, but must only make a submission for information purposes before the commencement of building [6].

The latest revisions of the NBR introduced Category 1 buildings. Government subsidized housing resort under this category. A Category 1 building has a maximum floor area of 80 m²; this building class allows different resistances to rain penetration, structural deflection limits, lower maintenance requirements and natural lighting levels, etc.

Revised Norms and Standards for government subsidized housing

The Department of Human Settlements reviewed the prescribed Norms and Standards for all government subsidized houses in an attempt to address pertinent issues from the revised requirements of SANS 10400. Additional features were included, supplementing the original requirements of the government-subsidized house [5]. These included the installation of a ceiling with the prescribed air gap for the entire dwelling and the installation of above-ceiling insulation comprising a 130mm thick mineral fiberglass blanket² for the entire house, using smaller sized windows and installing special low Emissivity (clear and opaque) safety glass for all prescribed window types. The plastering of all internal walls and applying a form of rendering on external walls were also added.

Financial impact of additional cost items

The additional cost requirements applicable to the 40 m² house, amounts to 12 % of the building costs and approximately 10% of the total project costs. Using the official housing backlog together with the current budget allowance for the basic dwelling unit, the cost implication of introducing the requirements of the revised NBR is R23,736,321,000.00 (€1,682,454,168.80).

Passive design as a goal

According to the Department of Minerals and Energy (DME), houses and other buildings in South Africa are seldom designed with energy consumption or energy efficiency in mind [7]. Specific mention is made of the energy characteristics of low-cost housing. The DME indicates that low-cost housing could be rendered 'energy smart' through the utilization of elementary passive solar building design practices, resulting in fuel savings of up to 65% [7].

² A performance approach to specification is suggested as an alternative where the roofing material and insulation used should achieve a total minimum R-value = 3,67 m²•K/W (or equivalently to m²•°C/W). [7] [8]

The DME Report No. 2.34-33 titled *Energy Efficiency: Energy and Demand Efficiency for Commercial Buildings* identifies passive solar design criteria for commercial buildings [8]. Among others, these include Orientation, Overhangs and shading, Insulation, Windows, Thermal mass, Layout and configuration as well as Day lighting.

Using cost as selection criteria, it is evident that specific items, from the aforementioned list, are applicable to the low-cost residential sector of South Africa. The above aspects in isolation will not be able to address existing (and future) energy consumption in the built environment. It is argued that the expansion of the aspects, as listed in Table 2 below, could contribute to a more sustainable built environment, whilst limiting additional costs.

Table 2: Refining the exiting NBR passive design criteria

Passive design requirements with no building cost implication	
1. Orientation	<ul style="list-style-type: none"> The functional aspects of building design in warm climates (with particular reference to thermal and ventilation considerations) was studied extensively by the National Building Research Institute, at the Council for Scientific and Industrial Research in Pretoria. According to van Straaten, in South Africa, “[t]rue north/south orientation... is generally considered best for all buildings ... because the windows can then be protected almost completely by relatively simple fixed exterior shading devices in the form of horizontal projections.” [9] The majority of habitable rooms should face North, or within 14° East of North, or within 14° West of North. [9]
2. Natural light (This existing regulation is currently not being implemented; see Part O of the NBR [10])	<ul style="list-style-type: none"> Each habitable room should have a total window area of at least 10% of the floor area (or 0,2 m²) for natural lighting [11], as required in the existing editions of SANS 10400.
3. Ventilation (This existing regulation is currently not being implemented; see Part O of the NBR [10])	<ul style="list-style-type: none"> Each habitable room should be naturally ventilated, using openable windows of at least 5% of the floor area (or 0,2 m²) for ventilation [11] , as required in the existing editions of SANS 10400. The design (on plan and section) should integrate cross ventilation, corresponding with the dominant wind direction for the area. [9]
Passive design requirements with limited building cost implication	
4. Shading of openings in northern walls: Exposed glass surfaces	<ul style="list-style-type: none"> Exposed glass surfaces in north-facing walls should have a protective roof overhang and/or shading device (i.e. shutters, screens or trees). [9]
Passive design requirements with building cost implication	
5. Storm water harvesting	<ul style="list-style-type: none"> Against a global rainfall average of 962.7 mm per year, South Africa receives a mean annual precipitation of 500 mm, making it the world’s 30th driest country. The introduction of gravity fed rainwater-harvesting systems with storage tanks could utilize this scarce resource.

Conclusion

Despite different opinions regarding the extent of the current housing shortage, the largest part of the South African population relies on government subsidised housing. This represents the biggest spatial need in the South African built environment. The scale of the housing need

exacerbates the cost implication of introducing new sustainability measures. The unique socio-economic circumstances in South Africa and the prevalent climatic conditions warrants a different view to limiting energy consumption in the South African built environment. Current planning and construction practices for low cost housing do not take cognizance of passive environmental design. Presently, low cost housing is exempted from the NBR, and the existing edition of the NBR does not include pertinent passive design measurements. Further studies into these aspects should be conducted to limit environmental impact, reduce operating costs while providing a more habitable built environment.

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Adapting Building Regulatory Systems to Better Address Climate Change Impacts

Note: This paper has been peer reviewed by the World SB14 Barcelona Scientific Committee

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Brian MEACHAM, Fire Protection Engineering and Architectural Engineering, Worcester Polytechnic Institute, Worcester, MA, USA (bmeacham@wpi.edu) – *Adapting Building Regulatory Systems to Better Address Climate Change Impacts* (session moderator)

Abstract: *The contribution of the buildings sector to climate change is significant and widely acknowledged [1]. At the same time, buildings are vulnerable to the effects of climate change, including drought, wildland fire, flooding, snow loads, storm (wind) intensity and more. While these issues have been studied to various extents, the building regulatory systems, within which buildings are effectively designed and operated, have received almost no attention. To complicate the situation further, the building regulations and codes themselves have not holistically considered how changes in materials and systems meant to decrease carbon emissions might actually be increasing building vulnerability. These challenges are amplified in building regulatory systems where measures of performance are unclear, responsibility for design, approval and enforcement is diversified, and no single entity has an understanding of the holistic building performance. Given the convergence of these factors, strong consideration must be given to restructuring of building regulatory systems to better understand and address holistic building performance in the face of climate change adaptations, physical impacts resulting from climate change effects, multiple and potentially competing policy directives, government resource limitations, and an increasing reliance on self-control via market mechanisms. If the system as a whole is not adequately considered, history has shown there can be opportunities for significant regulatory system failures [2-5].*

Keywords: *Building Regulatory System; Performance-Based Building Regulation; Climate Change*

1. The Problem

Building regulatory systems are complex systems of systems. They typically include some type of legislative mandate for building regulation and control, a building code, which includes regulatory requirements for the design and construction of a building, reference standards which address testing, installation and maintenance, and some type of building control. They may include reference to code of practice for designers and others, created by professional organizations. Minimum competency requirements for practitioners, and mechanisms to assess and license those practitioners, may be included as well. In some cases, market-based mechanisms, such as ‘private certification,’ ‘self-regulation,’ or third-party market controls, as might be set by the insurance industry, may exist as well. While complex, the system has worked generally well when focused on issues of occupant health and safety. Increasingly, however, building regulatory systems are becoming complicated by policy mandates originating from outside of the historical realm of building regulation, including environmental and resource legislation (energy, water, material), which are in some cases imposing ‘competing objectives’ and difficult enforcement challenges. This includes energy performance legislation leading to measures which create fire safety challenges, and



planning/zoning legislation which can create fire safety challenges (densely grouped buildings, small roadways) and in some cases the construction of buildings in at-risk locations (prone to flooding, sea-level rise, etc.). Such challenges are also seen with market-based, voluntary approaches aimed at increasing energy performance of buildings, such as BREEAM, LEED, and others. Such approaches are developed completely outside of the building regulatory system, and their implementation is often targeted at existing buildings, for which building regulatory oversight is typically less than with new construction.

As a result, while the number of governmental policies and market approaches aimed at increasing the sustainability of the built environment developed in recent years is considerable, their success in facilitating a sustainable built environment has arguably been limited [6]. The stakeholders in the construction and building regulatory markets are fragmented and not working effectively together [1,6], inconsistent levels of performance is being realized through voluntary measures [7,8], there are incomplete building performance measures, monitoring and enforcement mechanisms [6,9] and increasing liability concerns [10]. The fragmented regulatory approach and introduction of competing objectives has led to unintended consequences being introduced, some of which present considerable risk to building occupants. The push for new technologies for energy efficiency and performance in building is introducing a wide range of hazards, including structural hazards due to moisture-related failures of enclosed structural systems [2-5], health hazards related to mold and indoor air-quality due to weather-tight buildings [11], fire and health hazards due to the flammability of thermal insulating materials [12-14], fire and smoke spread potential through the use of double-skinned façades [15], and fire hazards and impediments to emergency responders associated with interior and exterior use of vegetation (shading, green roofs, etc.), among others [14]. The ‘competing objectives’ between sustainability and fire safety are particularly complex due to the multidimensional aspects of each. For example, timber is ‘sustainable’ but also is combustible, so if not addressed appropriately can present a significant fire safety hazard [14]. High strength concrete requires less material and is more sustainable than regular strength concrete, but can be highly susceptible to spalling during a fire if not modified [16]. These ‘competing objectives’ can result in significant performance challenges for buildings.

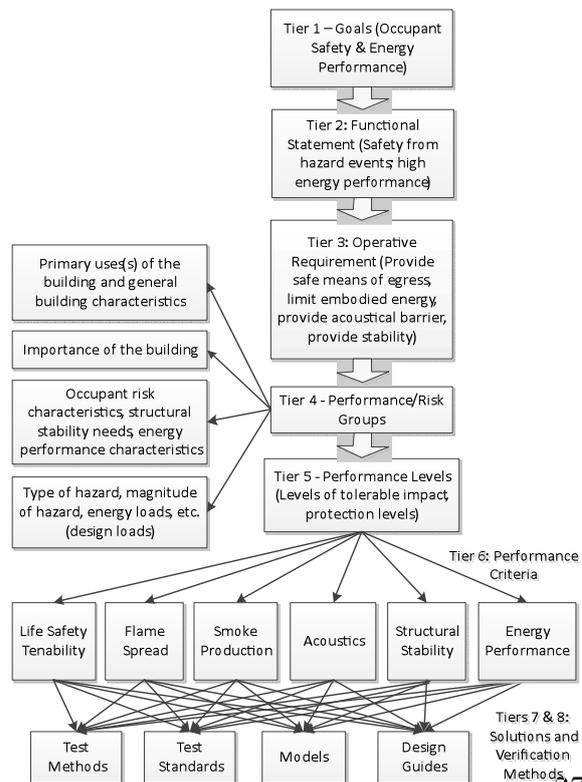
2. What Can Be Done?

In part, the fragmented approach to building regulatory development and control, and the resulting competing objectives and creation of potentially hazardous conditions associated with the noble goal of becoming more sustainable, can be related to the lack of a broadly agreed framework for holistically describing and assessing building performance across all societal objectives. Buildings, like building regulatory systems, are a complex system of systems. To function properly, all aspects must be in sync. This is difficult to control if there is no framework within which to test the system. This situation can become exacerbated with deregulation and downsizing of government control if there is not clear guidance to the private sector entities who take on responsibility for the holistic performance of buildings. To

address these issues, change is needed across the whole of the building regulatory system, including policy formulation, structure of regulations, and means of ‘checks and balances’ within the system. In some countries, change to the building regulatory development process may be needed. In all cases, a more robust building regulatory framework will be beneficial. In all cases, more explicit identification, acceptance and control of risk needed. In addition, more data, tools and methods are needed relative to the holistic performance of buildings across all required attributes. That is, instead of focusing primarily on one attribute for a specific policy objective or solution (e.g., thermal performance for an energy efficiency objective), the focus needs to be on adequately characterizing the performance across all essential areas (e.g., thermal performance, fire performance, health effect, etc.) and developing processes, tools and methods to assess influences of one objective on another. Finally, building regulatory systems need to do a better job of addressing existing buildings. While issues associated with safety performance have been known for decades (e.g., large life-loss events lead to building code changes, in some cases retrospectively), the extent of issues associated with climate change (e.g., energy performance) and resilience to impacts of climate change (e.g., higher strength storms, coastal and other flooding concerns, etc.) have only started to be a focus. The situation is complicated by voluntary measures in some areas, such as energy performance rating schemes resulting in building changes which reduce safety.

3. Starting Point: The IRCC Performance-Based Building Regulatory Framework

Based initially on a structure outlined by the Nordic Building Codes Committee (NKB) in the late 1970s, a model for performance-based building regulations has been suggested by the Inter-jurisdictional Regulatory Collaboration Committee (IRCC) [17-19]. Illustrated in Fig. 1, the model assumes that regulatory provisions are based on policy goals (essential interests of the authorities), and through increasing levels of detail, functional and operational requirements are described. Functional requirements provide qualitative statements about the desired function of buildings or specific building elements. Operative requirements provide a level of detail that can be applied to design and construction, ideally presented as quantitative requirements, and expressed in terms of specific performance criteria or expanded functional descriptions. Performance or risk groups aim to provide a mechanism for grouping requirements for different building uses (e.g., residential, business, assembly) based on common risk or performance targets. Performance levels define





the common targets under various conditions or events. Instead of prescribing a single set of design specifications for compliance, the approach requires that instructions or guidelines be provided which outline how compliance with the functional and operative requirements is to be verified. These instructions or guidelines can include engineering analyses, test methods, measurements and simulations. In addition, examples of acceptable solutions, deemed to satisfy the building regulations, are to be provided. Several countries are currently operating with building regulations which fit some, if not all, aspects of the model [17]. The IRCC model is attractive because it places the focus on goals and objectives for the building, and allows for a variety of mechanisms to be used to demonstrate compliance. However, the model does not provide guidelines for how to apply the process / framework to the revision of existing building regulations, or to development of new regulatory requirements and supporting components, such as for sustainability and climate change. In particular, gaps exist in guiding users as to how to best identify and incorporate a suitably broad and informed set of stakeholders for identifying appropriate performance and risk levels, in understanding and applying suitable decision-making processes in the performance and risk criteria setting process, and connection of quantified design criteria to performance expectations. These areas are critical in advancing the applicability of the model for addressing new and emerging issues, such as climate change impacts on building.

4. Where Do We Go From Here?

To move forward, several steps are needed. First, there needs to be a shift in thinking from viewing buildings as a collection of independent systems, to viewing buildings – and building regulatory systems – as complex systems of systems with strong interrelationships between subsystems and overall building performance. Increasing energy performance should not be considered without assessing impacts to structural performance, indoor air quality, fire performance or other attributes. Reducing material should not just be viewed as a cost savings or sustainability measure, but resulting structural performance, fire performance and related factors need to be considered. Viewing the problem as being a complex systems problem is not new [e.g., 5, 20], but thus far a true shift in thinking has not occurred, and the ‘silo’ based approach is creating new hazards and risks as it tries to mitigate others.

Second, a broader set of stakeholders is required to feed into the regulatory development and control process to help assure the key societal and policy objectives are met. Experience within the countries participating in the IRCC shows that building regulations are largely formulated by a small group of specialists, be they codes- and standards-making committees, bureaucrats, consultants or some combination [17]. These experts may consult other experts for specific issues, when deemed appropriate, and they may also consult the public. However, given the relatively small numbers of experts involved, it is questionable if the process results in a broad enough discussion of critical issues – technical, political or societal. This has been observed by others in the area of sustainable design and construction as well [e.g., 20-22].



Third, in addition to breaking down the ‘silo’ based approach and broadening the stakeholder participation in the building regulatory process, governments need to find ways to likewise break down the silos between departments and agencies responsible for the various parts of the problem, and get the right participation from each organization together in the regulatory policy-setting stage. It is impossible to control the changing nature of political agendas. However, the translation of political agendas and policy directives into regulation is largely a function of civil servants, and much more coordination can occur at the upper levels of governmental departments and agencies.

Fourth, while the IRCC model provides a good starting point, advancements are needed in several key areas. Again, these are unfortunately not new, having been identified at least ten years ago [19]. Methods need to be developed to help identify emerging hazards and threats, the likelihood of the hazards or threats occurring, the potential consequences, public expectations with respect to protection, available mitigation technology, cost, and deciding who will pay. Assuming societal expectations can be identified, and performance goals developed, tools, mechanisms and criteria that are necessary to define, measure, calculate, estimate, and predict performance must be developed. To make sure holistic performance is achieved, more research is needed to characterize and define the linkages and interrelationship between goals, objectives, criteria, test methods, and design tools and methods. The right balance of regulatory and market mechanisms are needed for optimization of the system. While some new thinking in risk-informed performance-based regulatory and design structures have been explored [e.g., 23,24], and tools for assessing the interrelationships of performance objectives have been outlined [24], considerably more advances are needed.

Fifth, government needs to recognize that one of the biggest challenges with energy policy, resilience to climate change, and health and safety of occupants in buildings is how to achieve objectives in these areas within existing buildings. In most countries the building regulations do not address existing buildings, except when significant renovation or change of use occurs. To truly make advances in energy, resiliency and safety performance across the built environment, building regulatory systems need to address existing buildings. While this is being done in some areas, like the Energy Performance of Buildings Regulation (EPBR), the silo-based approach (i.e., considering energy but not safety) runs the risk of creating the types of unintended consequences identified above (e.g., fire, health or structural safety hazards).

Finally, in order to address the wide range of issues, a new process for building regulation development would be beneficial. It is suggested that the approach utilize an analytic-deliberative process to identify the pertinent issues, obtain needed data and information regarding holistic building performance, and facilitate decisions amongst the range of actors involved. An approach such as proposed for the development of risk-informed performance-based building regulations [25], coupled with advancements on the IRCC Hierarchy (Fig.1), would seem to serve this purpose well.

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