WORLD SUSTAINABLE BUILDING 2014
BARCELONA CONFERENCE

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CONFERENCE PROCEEDINGS
VOLUME 1

WORLD SB14 BARCELONA
October 28/30th 2014

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

The Conference was organised by GBCe (Green Building Council España), co-promoted by iiSBE, UNEP-SBCI, CIB and FIDIC, and counted on the participation of World GBC*.

This volume gathers papers presented in the oral sessions from the Conference area “Creating New Resources”, presented at World SB14 Barcelona on the afternoon of day 1 of the Conference. All the papers in this volume were double blind peer reviewed by the Scientific Committee of World SB14 Barcelona.

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***iiSBE:** International Initiative for a Sustainable Built Enviroment
UNEP-SBCI: United Nations Environment Programme - Sustainable Buildings and Climate Initiative
CIB: Conseil International de Batîment
FIDIC: International Federation of Consulting Engineers
World GBC: World Green Building Council

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Session 7:

What role must the user play in sustainable building?

Chairperson:

Colin, Brigitte

Consultant in Architecture, Cities and Urban Policies. UNESCO Natural Sciences Sector

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Impact of occupant behavior on space heating demand in the retrofit of multi-family residential buildings

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Abstract: *The parameters that influence the energy consumption of a building can be divided into outdoor climate, design and thermal quality of the building (design, orientation, thermal performance of components and systems, etc.) and behaviour pattern (use of the building and its systems: heating setpoints, ventilation, etc.). When assessing potential energy savings due to different renovation scenarios is essential to take into account the impact that human behaviour may have on the building's performance once renovated. In this way, you can evaluate more accurately the range of energy demand of the building according to different settings of use.*

This paper presents some findings from two case studies; a total of 15 households in two residential buildings have been monitored and modelled in Energy Plus. Distinct patterns of behaviour have been simulated while the thermal performance of the envelope is improved to evaluate the impact of occupant in the heating demand of different renovation scenarios.Energy retrofit, occupant behavior, space heating demand, building monitoring, energy simulation

Introduction

Occupants' behaviour in buildings has a great impact on energy use. Numerous studies comparing the expected and measured consumption in residential buildings establish that human actions could be responsible for a deviation between 20 and 40%, reaching in extreme cases more than 100% of deviation.

In conservation and energy economics the rebound or take-back effect is a term that describes the shortfall between the predicted and actual energy savings after an energy efficiency improvement. A poor execution of building works and occupant behaviour are to be blamed.

It is essential to assess the energy savings of a retrofit to a certain level of accuracy and, therefore, human behaviour has to be considered in building energy simulation.

This paper investigates the impact of occupant behaviour on heating demand of two case studies. It shows the unpredictable human behaviour, mainly in buildings with individual heating systems, and its impact on energy use through actual data. By means of simulating, the impact of different behaviour variables on energy demand is analysed, just like the impact of different behaviour patterns when assessing different levels of energy retrofit.

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Methodology

1.- Building monitoring

Two multi-residential buildings located in Pamplona have been studied. TH consist of two towers joined at one side with 96 dwellings; whereas CB is a residential complex consisting of a linear block and a closed block typical from the expansion areas. The main parameters that define the buildings are listed in Table 1.

	TH	CB
Number of dwellings	96	152
Heated net floor area (m^2)	13886	9800
Heated volume (m^3)	36104	26459
Average area per dwelling (m2)	144.6	64.5
Facade surface (m2)	9459	6516
Facade U-value	1.92	2.09
Roof surface (m2)	1504	2725
Roof U-value	0.49	2.58
Window surface (m2)	1842	1899
Window U-value	3.3 (f 2.2)	3.5 (f 2.4)
Sup. Envelope/Volume	0.35	0.45
% Window/Facade	0.24	0.29
Heating system	Central, 2 heating rooms	Individual

Table 1 & Figure 1. Table with main building characteristics of the two buildings monitored. TH on the upper photography and CB bottom one.

Both buildings were monitored during winter 2012-2013. The tests carried out consisted of: thermographic study, blower door test, heat flux meter and installation of temperature and humidity data loggers in representative households (in different orientations or at different height in the building). With this information it is possible to determine more accurately the condition of the building and its use so that the uncertainty of the simulation model used to calculate the energy savings derived from a retrofit is reduced.

2.- Setpoint temperatures and heating schedule

The recorded temperatures in both buildings show very different behaviours. In TH, all flats have a very similar pattern with temperatures ranging between 20 and 25 ° C, due to the fact of having a central heating system without neither individual regulation nor energy meters. However, in CB, each occupant has a single system so that the recorded temperatures are much lower, between 15 and 22 ° C with very different behaviours between dwellings.

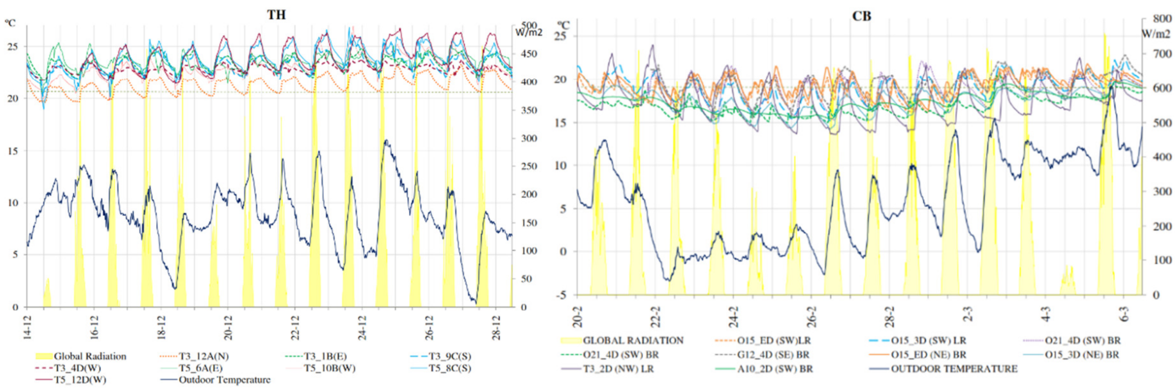

Figure 2. Recorded temperatures in building TH and CB during winter 2012-2013.

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In TH the mean of the daily average temperature in the living room of the monitored dwellings is 23.16ºC, however if we only consider the hours when the heating system is in use, this temperature reaches 23.67ºC. It is noteworthy that the absolute minimum temperature recorded is, in most cases, greater than 20ºC. Nevertheless, the temperature recorded in the main bedroom was normally around 3ºC lower than in the living room.

	T3				T5					
	12A(N)	1B(E)	9C(S)	4D(W)	6A(E)	10B(S)	8C(S)	12D(W)	AVER.	EXT. T
T average daily max	22.3	24.5	24.4	23.5	24.7	24.3	25.5	25.9	24.4	12.3
Time	17:09	16:21	15:44	19:01	15:05	15:09	17:53	19:27	16:58	16:48
T average daily min	20.3	22.4	21.9	22.3	22.4	21.5	21.7	22.5	21.9	0.7
Time	10:55	12:25	10:41	10:20	10:39	9:39	12:35	11:45	11:07	6:00
T average daily	21.4	23.5	23.3	22.9	23.6	22.9	23.8	24.0	23.2	8.5
Daily oscillation	2.0	2.4	3.4	1.2	2.2	3.2	3.7	3.1	2.7	7.9
T max	23.3	25.8	25.5	24.0	25.3	27.3	28.1	26.7	25.8	17.4
Tmin	19.6	21.2	20.2	21.8	20.4	19.6	19.0	21.3	20.4	-3.0

O15				O21	A10		T3	G12		
O15_ED (SW)LR	O15_ED (NE)BR	O15_3D (SW)LR	O15_3D (NE)BR	O21_4D (SW)BR	A10_2D (NE)LR	A10_2D (NE)BR	T3_1 (NW)LR	G12_4D (SE)BR	AVER.	EXT TEMP.
20.8	21.0	21.7	19.0	21.0	18.4	18.3	21.5	21.5	20.3	12.9
15:46	9:06	10:46	15:43	14:27	9:50	12:30	19:39	11:05	13:12	14:34
18.1	18.5	18.3	17.4	17.1	16.9	16.5	16.1	17.5	17.4	3.8
12:50	14:12	11:13	10:21	12:55	13:11	11:20	12:43	10:55	12:11	9:10
19.0	19.4	19.4	17.9	18.8	17.1	17.5	18.0	19.7	18.5	7.9
3.1	2.5	3.4	2.2	4.3	0.9	1.9	6.3	3.5	3.1	19.2
21.4	21.8	23.1	20.5	22.2	20.7	19.7	24.0	22.8	21.8	-3.4
16.1	16.5	15.2	14.2	15.3	15.0	15.5	13.6	15.5	15.2	6.8

Table 2. Summary of the average daily maximum, minimum and average, daily oscillation and absolute maximum and minimum temperature in the monitored dwellings of TH and CB.

The temperature pattern of CB differs greatly from TH. The mean temperature of average daily temperatures of all dwellings is 18.5 º, whereas the average maximum and minimum are 20.19 ºC and 17.53ºC respectively.

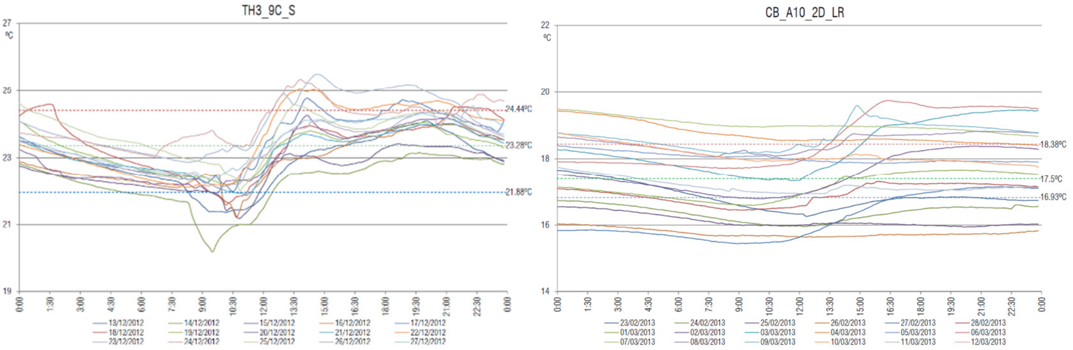

Figure 3. Daily pattern behaviour in two different dwellings, one of each building. Average daily maximum, mean and minimum temperature in dotted lines.

Figure 3 shows the temperature recorded in two living rooms of different dwellings in TH and CB respectively. In CB_A10_2D the heating is scarcely used, the temperature shows a steady linear increase from midday until 16:30 but the temperature isn't increasing above 20ºC, the occupant didn't used the heating in the living room during these days so the heat comes from other heated stays in the dwelling, main bedroom, or from adjacent dwellings. In this plot there isn’t any sharp change in temperature that can be linked to ventilation. In TH3_9C, temperature increases faster until 2:00 pm, with a posterior decrease (when there is no longer solar gains) maintaining a steady temperature until the heating is off.

3.- Heating consumption

Data on energy consumption are available from TH and some of the monitored dwellings in CB. This data in all cases includes the energy consumption for DHW and therefore, some processing was needed to obtain the energy use associated only to space heating.

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TH has two heating rooms, one per tower. The heating demand of TH3, calculated from the gasoil consumption of the last years, is around 69.5kWh/m^2; in TH5 there is information available from the last 7 years and the average energy demands is a bit higher, 71.5kWh/m^2. However, in CB every dwelling has its own heating system, which ranges from gas boilers to electrical radiators or fire places. There are data from five dwellings which are: 41 (only heated areas 71.7), 59.4, 68.5 (only heated areas 88.7), 114.3 and 160 kWh/m^2 that correspond with dwellings O15_3D, O21_4D, A10_2D, T3_1 and G12_3 respectively. This wide dispersion of demands clearly shows the importance of occupant in energy use. However, T3_1 and G12_3 have a closer behaviour to what could be defined as comfortable; that's why the energy demand of this building should be closer to these values.

4.- The building model

First of all, both buildings have been modelled and calibrated in EnergyPlus according to the data gathered during the monitoring and the surveys performed to the occupants. In CB due to the variability of the recorded behaviour and the fact that most households do not reach comfortable temperatures, the calibrated model has been defined to ensure occupant comfort.

The occupant behavioural variables that have an impact on heating demand can be divided into: use of heating system (temperature setpoint and schedule of use), ventilation, internal gains (occupancy and use of appliances) and heated spaces. There are numerous papers in which occupancy patterns are defined in terms of these variables [1-3].

In this case, four models are going to be simulated to evaluate the impact of occupant on energy use: Model A, which correspond to the calibrated model; Model B, modelled according to the Spanish building code and two models that represent extreme behaviour, Model C, expender and Model D, saver.

Model C correspond to a household without any concern in energy saving, the temperature setpoint is high and ventilation time is longer. On the contrary, Model D represents a pattern in which the use of heating is scarce, only for a couple of hours per day in the occupied rooms, and ventilation is minimum to avoid thermal losses. The values assigned to each variable can be found in Table 3.

		Model A - calibrated	Model B - normative	Model C - expender	Model D - saver
Use of heating system	Temperature setpoint (°C)	23.5°C living room/21°C main bedr. (TH) 20.5°C (CB)	20/17 °C	22.5/18 °C	20 °C
	Schedule (weekdays)/*(weekends)*	12-22 (no night setback)	08-23 (night setback)	08-23 (night setback) *09-24*	19-21 (no night setback) *19-21*
Ventilation	Ventilation (ach^{-1})	4.00	0.98(TH)/0.68(CB)	4.00	4.00
	Schedule (weekdays)/*(weekends)*	07:30-08 *08:30-09*	00-24	07-08 *08-09*	06:50-07 *07:50-08*
Internal gains	Lighting (W/m^2)	0.1/1/0.5/1.5 *0.1/0.75/0.5/1.5*	0.44/1.32/2.2	0.44/1.8/0.9/2.7 *0.44/1.35/0.9/2.7*	0.05/0.75/0.38/1.13 *0.05/0.653/0.38/1.13*
	Schedule (weekdays)/ *(weekends)*	00-07/07-09/ 09-18/18-24/ 00-08/08-17/ 17-22/22-24	00-01/01-08/08-24	00-07/07-09/09-18/18-24/ *00-08/08-17/17-22/22-24*	00-07/07-09/ 09-18/18-24/ *00-08/08-17/ 17-22/22-24*
	Appliances (W/m^2)	0.6/1.6/1/2/1.2/2.25 *0.6/2/1.2/2.25*	2.2/0.44/1.32	0.8/2.88/1.8/3.6/2.16/4.05 *0.8/3.6/1.8/4.05*	0.3/1.2/0.75/1.5/0.9/1.69 *0.3/1.5/0.85/1.69*
	Schedule (weekdays)/ *(weekends)*	00-07/07-09/09-13/13-15//15-19/20-24/ *00-08/08-17/17-22/22-24*	00-01/01-08/08-24	00-06/07-08/09-12/13-14/15-19/20-23	00-06/07-08/09-12/13-14/15-19/20-23
	Occupants sensible/latent (W/m^2) (weekdays)/(weekends)	0.9/1.07/0.67/1.33/0.8/1.5 (sensible) 0.57/0.67/0.42/0.84/0.5/0.95 (latent) *0.9/1.33/0.67/1.5 (sensible) 0.57/0.84/0.95 (lantent)*	2.15/0.54/1.08 (sensible) 1.36/0.34/0.68 (latent) *2.15 (sensible) 1.36 (lantent)*	1/1.2/0.67/1.33/0.8/1.5 (sensible) 0.25/0.67/0.42/0.84/0.5/1 (latent) *1.2/1.33/0.67/1.5 (sensible) 0.25/0.84/1 (lantent)*	1/1.2/0.67/1.33/0.8/1.5 (sensible) 0.25/0.67/0.42/0.84/0.5/1 (latent) *1.2/1.33/0.67/1.5 (sensible) 0.25/0.84/1 (lantent)*
	Schedule (weekdays)/*(weekends)*	00-07/07-09/09-13/13-15/15-19/20-24 *00-08/08-17/17-22/22-24*	00-08/08-16/16-24 *00-24*	00-07/07-09/09-13/13-15/15-19/20-24 *00-08/08-17/17-22/22-24*	00-07/07-09/09-13/13-15/15-19/20-24 *00-08/08-17/17-22/22-24*
Use of space	Rooms heated	All rooms	All rooms	All rooms	Living room and two bedrooms

Table 3. Definition of behaviour models and valued assigned to each variable.

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In any case more extreme behaviours can be found, for example, the actual setpoint in TH is higher than the one defined in Model C (although in model A not all the dwelling is heated until 23.5ºC) or in central heated buildings ventilation may occur while the heating system is working. Nevertheless the goal of this study is to analyse representative behaviours.

In order to study the impact of these behaviours in the energy consumption of the retrofitted building three scenarios have been defined in which the thermal performance of the facade and the windows, and the air tightness of the envelope is progressively improved. The parameters used are summarized in Table 4.

	Facade			Windows			Infiltration		
		TH	CB		TH	CB		TH	CB
	Description	U value		Description	U value/g value	U value/g value	Description	ach^{-1}	ach^{-1}
Baseline	Doble brick facade (TH4.5 cm of air cavity /CB 8cm of air cavity)	1.92*	2.09*	Different condition, average: wood frame/double glass	f:2.2 g:3.3/0.8	f:2.4 3.5/0.8	Obtained by Blower door test	0.55	0.65
Scenario 1 - Only facade	8 cm external insulation EPS (λ=0.038W/m2)	0.69*	0.58*	No improvement	f:2.2 g:3.3/0.8	f:2.4 3.5/0.8	Minimum improv. due to external insulation	0.50	0.59
Scenario 2 - Facade + windows + infiltrations	8 cm external insulation EPS (λ=0.038W/m2)	0.58*	0.41*	wood frame/ 4.12LowE.6	f:1.8 g:1.6/0.58	f:1.8 g:1.6/0.58	Replacement of windows	0.33	0.39
Scenario 3 - Facade + windows + infiltrations	16 cm external insulation EPS (λ=0.038W/m2)	0.58*	0.41*	wood frame/ 4.12LowEar.6	f:1.8 1.3/0.58	f:1.8 1.3/0.58	Replacem. of windows, improved air tightness	0.22	0.26

* This is a global value taking into account the decrease of thermal resistance due to thermal bridges.

Table 4. Main thermal properties of the retrofit scenarios evaluated.

5.- Sensitive analysis

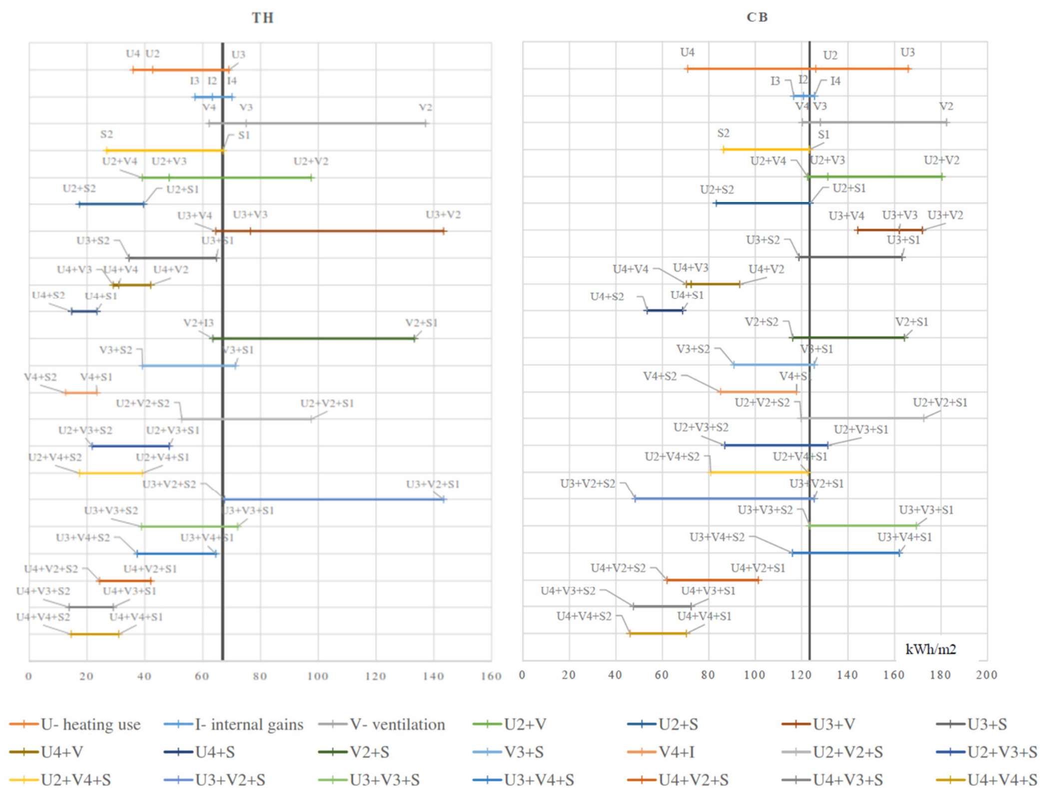

Figure 4. Sensitive analysis of behaviour parameters and their possible combination

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First of all, a sensitive analysis has been conducted with the calibrated model in order to evaluate the influence of each parameter individually and when they are combined in different ways. In Figure 4, the number of the parameter corresponds to the different behaviour according to Table 4 being 2, the normative value; 3, expender and, 4, saver behaviour. The vertical thicker grey line represents the demand of the calibrated model.

In TH, the parameter that that influences most the results is the ventilation, whereas in CB is the use of the heating system, followed by ventilation. This is due to several reasons, first, because the ventilation rate is defined according to the normative and in this case ventilation rate in TH is bigger than in CB; secondly, TH is a building more compact than CB and therefore thermal losses through the envelope have lower influence on the demand than the ventilation does.

These graphs already show us the influence of occupant on energy use. In TH, the demand multiplies by 2.2 when the ventilation is constant at almost one renovation per hour. In CB, setpoint temperature has a higher impact increasing the demand almost by 1.5 when the building is heated at 22.5ºC during daytime hours. In this case we also can see the impact that a reduced use of heating has (U4, lower part of the graphs). The impact of internal gains on energy demand is small so its combination with the other parameters hasn't been done.

6.- Results

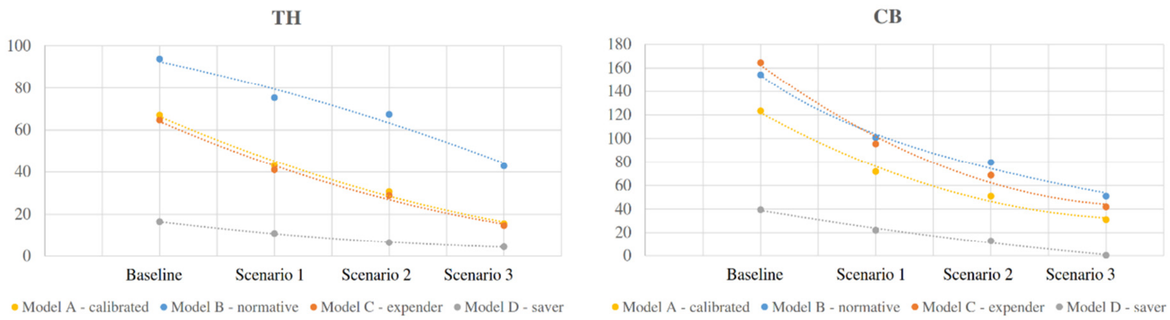

Figure 5. Impact on energy demand of human behaviour in different retrofit scenarios in TH and CB.

The actual energy use in TH is slightly bigger than the demand of model defined as expender behaviour, this is due to the very high temperature setpoint throughout the day. The normative behaviour differs significantly to the calibrated one due to the excessive ventilation in Model B. In CB, the normative model is closer to the calibrated one; nevertheless, many of the monitored dwellings have a closer behaviour to Model D, saver use. In this model the savings are minimal due to the limited use of the heating system, so it is indispensable to know the actual use of the building when predicting the energy savings derived from a retrofit.

If we improve the building envelope and occupant behaviour remains the same after the retrofit, the energy demand will move along the yellow line. However, if the temperature setpoint or ventilation will increase the actual savings will be lower than predicted, being possible to be in a situation where the initial consumption is even lower than after the renovation; for example, in TH this would happen if, starting from a calibrated model, we behave as in the normative model after the retrofit Scenario 1 or 2.

In both cases, if we carry out a deep retrofit the impact of occupant behaviour on energy demand is reduced and it is less likely that the rebound effect occurs.

Conclusion

Two residential buildings have been monitored and simulated in order to assess the impact of occupant behaviour on energy demand in retrofitted buildings. Several differences have been found between them. First of all, the monitored data shows that the building with central heating was heated to much higher temperatures than dwellings with individual heating systems. No significant changes are detected from the temperature pattern of the different dwellings. On the contrary, dwellings with individual heating systems have a very variable pattern of use; there are even some cases where the heating is rarely used. Therefore, it is essential to know the occupant behaviour and the actual consumption of the building in order to estimate accurately the energy savings.

These energy savings depend on the initial thermal quality, design, and the behaviour of the occupants. Sensitivity analysis allows us to understand which parameters have the greatest influence on energy demand so that the retrofit measures are focused on these components or actions oriented to change certain occupant behaviour.

In CB, with an initial worse thermal quality of its envelope and bigger ratio façade/heated floor surface, the use of heating is the variable that has the greatest impact on the energy demand of the building. In contrast, in TH ventilation is the most important factor in part due to the lower losses that occur through the envelope.

The rebound effect due to a change of occupant behaviour has been shown in Figure 5. Nevertheless, the likelihood or its extent of occurrence is considerably reduced when carrying out a deep retrofit. For this reason, in addition to greater energy savings, the fact that rebound effect is minimized, should be enough reason for governments to focus their policies on deep retrofit programs.

Bibliography

[1] Guerra-Santin, O. (2011). Behavioural Patterns and User Profiles related to energy consumption for heating. Energy & Buildings, 43(10), 2662-2672

[2] De Meester, T., Marique, A., De Herde, A., & Reiter, S. (2013). Impacts of occupant behaviours on residential heating consumption for detached houses in a temperate climate in the northern part of Europe. Energy & Buildings, 313. doi:10.1016/j.enbuild.2012.11.005

[3] Papakostas, K., & Sotiropoulos, B. (1997). Occupational and energy behaviour patterns in Greek residences. Energy & Buildings, 26(2), 207-213.

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Post-Occupancy Evaluation by the test families in five Model Home 2020 across Europe

Speakers:
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Abstract: *This paper describe the Post-Occupancy Evaluation (POE) of five families living, for one year, in the Model Home 2020. The houses are located in Germany, Austria, France and UK. The survey is carried out seasonally during the test year the family lives in the house allowing to capture and explore variation on a seasonal basis. The questionnaire is focusing on energy consumption and production, indoor climate and air quality, daylight and electric lighting, house automation, and sustainability. The results give an indication of what the families think of the houses, of its interior environment, and how the environment is experienced etc. In general, the families indicate high satisfaction with the indoor environment, better health, fewer sick days and improved sleep quality, that their expectations often are fulfilled, that house automation is acceptable, and being able to follow energy consumption and production increase awareness of their behavioural influence.*

Keywords: Model Home 2020, Post-Occupancy Evaluation, Interior Environment, Sustainability, Health and Sleep Quality Lorem, ipsum

Introduction

Through 2008-2012, six demonstration buildings are designed and constructed; one is a new-built office building, one renovation of a single-family house and four new-built single-family houses. The intent with the Model Home 2020 strategy is to combine excellent indoor environment with high quality homes mainly driven by renewable energy sources as contextually optimized design solutions [1-4]. Thereby, the houses are designed, built and constructed as state-of-the-art homes with the newest technological developments and high quality materials.

These houses are built to explore possibilities in future technical as well as perceived sustainability. All houses have automatic systems installed as to optimize indoor environmental conditions, for instance by automatically opening and closing windows to air out exhaust or warmed air, pull down solar shading to prevent too much solar gains or shut windows when raining. Sensors are installed in each house in each of the rooms to register indoor environment conditions (temperature, CO2 levels, relative humidity, lux) and regulate based on these values. A weather station is installed on the rooftop of the house to register outdoor weather conditions (temperature, rain, global illuminance, hours of sunshine and wind direction). These data are used to adjust the indoor environmental conditions to the comfort of the occupants. Four Model Homes 2020s houses LichtAktiv Haus (Germany) [1],

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Sunlighthouse (Austria) [2], Maison Air et Lumiére (France) [3], and Carbon Lighthouse (UK) [4], and their occupants are subjects to this paper.

Model Home 2020

LichtAktiv Haus was built in 2010 and the family moved in December 2011. LichtAktiv Haus is the first CO2-neutral modernisation of a so-called Siedlerhaus, a semi-detached house from the 1950s located in the Wilhelmsburg district of Hamburg. The innovative modernisation strategy combines maximum liveability with optimum energy efficiency. The once tight and closed structure of the building has been transformed into spacious rooms with high levels of daylight, providing occupants with the best living comfort. Natural ventilation ensures a healthy indoor climate. The refurbished house contains of two children's rooms, two bathrooms, a master bedroom, a central living area and a reading room. All rooms feature façade and roof windows that are positioned to ensure optimum distribution of daylight. The floor area of the house is 185 m^2, and the glass area is equivalent to 58 % of the floor area. To provide electricity and hot water solar collectors and photovoltaic solar cells were used – everything to cover energy demands of the house.

Figure 1. Photo of the LichtAktiv Haus (Germany) to the left and Sunlighthouse (Austria) to the right (Photo by Adam Mørk).

Sunlighthouse was built in 2010 and the family moved in February 2011. Sunlighthouse is Austria's first carbon-neutral, single-family home. The vision is to build a house with exciting and appealing architecture focusing on the sloping roof. The house must be generally affordable and therefore meet certain specifications of dimensions, material and appearance. Sunlighthouse provides an exceptionally high proportion of daylight and will achieve a positive energy balance by reducing its overall energy consumption and by using renewable energy. The net floor area of the house is 201 m^2, and the glass area is equivalent to 36 % of the net floor area.

Maison Air et Lumière was built in 2011 and the family moved in September 2012. Maison Air et Lumière is a new generation of active homes that puts the quality of life of its

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inhabitants at the centre of its environmental approach. The unique features of the house lie in intelligent use of the sloping roof to combine well-being and energy efficiency. The architectural concept is based on different roof pitches that increase its ability to capture sunlight, making it an energy-positive home. The pitched roof is part of France's cultural heritage. Roof pitches vary in steepness according to region and climate – and to meet the need for light and solar gain. Carefully positioned façade and roof windows bring in sunlight from all directions. The windows also fill the space with fresh air to ensure a comfortable living environment all year long. The 130 m² floor area extends over one and a half storeys, with the spaces under the roof put to full use, with a window-floor ratio nearly 1:3.

Figure 2. Photo of the Maison Air et Lumiére (France) to the left and the Carbon Lighthouse (UK) to the right (Photo by Adam Mørk).

CarbonLight Homes was built in 2011 and the families moved in January 2013 and April 2013. CarbonLight homes are the first new home in the UK designed and built to the new UK Government definition of zero carbon and will achieve level 4 of the Code for Sustainable Homes. They are designed to be real homes for real people with construction techniques suitable for use by mass house builders. CarbonLight Homes use nature in an intelligent way to maximise daylight and encourage a sustainable lifestyle. The design is open plan and incorporates high levels of daylight and natural ventilation intended to minimise energy consumption among residents and generate a sense of community. The homes show that common-sense design can be used to create inspirational sustainable houses that can be easily replicated by UK house builders. The net floor area of the houses is 230 m^2, and the glass area is equivalent to 24,5 % of the net floor area.

Post-occupancy Evaluation

In all ModelHomes 2020, a family will live in the house for a full year to help measure, monitor and assess what they think about each of the ModelHomes. The survey is carried out seasonally during the test year the family lives in the house allowing to capture and explore variation on a seasonal basis with approximately three months in-between. The intent with four replies per house is twofold. Firstly, this is to identify if the occupants experience their perception changes during the stay; for instance – is their perception of indoor environment, expression, comfort or automation changing through their stay. The second aspect to the seasonal distribution is to explore if seasonal changes in weather, and thereby for instance dynamics temperatures, daylight, influence occupant experience. The outcome with the post occupancy evaluation (POE) of the houses is to get indications, from the families, how successful the Model Home 2020 are, and if challenges or problems, what can be learned and improved.

The questionnaire, translated into their native language, is mainly focusing on energy consumption and production, indoor climate and air quality, daylight and electric lighting, house automation, and sustainability [5]. It is a set of questions relating statements about satisfaction/dissatisfaction with the focus area described above, about frequency of occupant interaction with elements of the house, and if the house fulfil expectations of the occupants. In this study, the advantage of using questionnaire is that it is easier to distribute several times, but the disadvantage is the limited number of houses studied, and thereby statistical tools that can be used to draw significant conclusions from survey. Anyway, by employing these questionnaire four times during each family test year, we get indications of users' reactions to the house as well as gaining a better understanding of what is most important in the house environment to focus on

Results

The questionnaire is divided in the following subjects:

- Demographic questions (9 questions)
- Energy (5 questions)
- Indoor climate (15 questions)
- Control Units (7 questions)
- Electrical, natural light view (11 questions)
- Environment and sustainability (8 questions)

The questions about satisfaction were made as sets of Likert-scales categorised as *very satisfied, satisfied, neither satisfied nor unsatisfied, unsatisfied,* and *very unsatisfied*. Questions about how comfortable the subjects are in their indoor environments are categorised on a five-point rating scale by: *very rarely, rarely, occasionally, frequently, and very frequently*. Finally, the questions about energy, environment and sustainability were made as sets of statements and categorised as a three-point scale *yes, very, yes to some extent, no normally not*, or as sets of five-point scales *strongly agree - strongly disagree*, and *very good – very bad.*

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The demographic questions about the family and their children (age between 0 and 9 years) show that most of the residents have a working week away from the house (one family member work from home a few days per week). When at home, they normally spend between 11 to 16 hours on weekday in the house, while longer time in the weekends (between 16 to 20 hours). When asked if they experience their health as better or worse compared to former home, there is a clear tendency that they feel their health is "better" (72%). They also experience that their sleep quality compared with former home is "better" (50%) or "almost the same" (39%), and when rating their children's sleep quality, the tendency is a bit higher ("better" 56%; "almost the same" 44%). Furthermore, they have a significant experience that they have "less" sick days (83%) than in their former home, and they state their general health all in all is "good" or "very good".

In general, the residents where, to some extent, conscious about their energy consumption, environmental impact on their daily behaviour, hot water consumption, electric lighting use, and media attention on global warming to their energy consumption. Interestingly, living in these houses for one year did not make the family members more conscious with these topics over time, rather reverse or indifferent. Most of the residents were aware, in their statements, that the PV panels and the solar thermal collectors do not produce the amount of energy needed for electricity and hot water, although there was a tendency of higher awareness of the hot water use at the end. Among the residents, there were slightly different response, but the tendency between the beginning and end of the year, show similarity. The residents felt good about knowing that the house produces much of its own energy requirement, and that climate changes had altered their behaviour, but they were more indifferent regarding spending on energy generating products. However, they liked the signalling value of the energy technologies used (PV panels and solar thermal collectors) and felt these technologies are well integrated in the design of the houses. They are generally "concerned" or "very concerned" about minding the environment as well as saving energy.

Generally, the indoor climate is rated as "very important" and the residents state most of the time that it is "good" or "very good" for the house in general and three rooms in focus (>90% state "good" or "very good"); the kitchen, the living room, and the bedroom. When the residents were asked to choose three conditions they would like to change to make the indoor climate more comfortable to live in, they reported less noise from the window opening systems, less peeping inside (privacy) and better electric lighting. Across all the houses, the residents are either "very satisfied" or "satisfied" with the temperature conditions in general (90%) and the three rooms in focus (>85% state "very satisfied" or "satisfied"). Most of the times, the temperature conditions is assessed as about right, but separated into the different season of the year, the winter and the spring/autumn is stated as time of the year when temperature is sometimes evaluate as varying, while few state temperature as too hot, even in the summer. The air quality is rated as "very acceptable" (78%) or "acceptable" (22%), and they state, in general, that they have not experience any problems at all. If they want to improve the air quality, they open the facade and roof windows, and make draught. The sound and acoustic conditions in the houses show more mixed evaluation. Generally, the satisfaction level is lower for sound and acoustic conditions (56% “satisfied”; 33% “dissatisfied”) than the other indoor climate conditions, due to the fact that the residents are more bothered by the sound of the facade and roof windows, when they automatically opens.

About house control system to operate the indoor climate, the residents state that the control unit most frequently used is the screen, remote control second, while manually operating is the least used unit. They are generally “very satisfied” or “satisfied” (>85%) with the way the house system operate the facade and roof windows, the indoor temperature, internal and external screen, and ventilation system (one house is natural ventilated). They have a clear feeling that the way the control unit operate the house support their needs, and it “easy” or “very easy” to use. It shows further that they “rarely” or “occasionally” use the control system to manually operate the facade and roof windows, internal temperature, but more frequently use the control system to operate the screening. When operating, there is a clear preference to use the screen/remote control, and not too often, they do it manually.

Between 67 and 89 % of the resident reported that they were “satisfied” or “very satisfied” with the artificial lighting in the house in general and three rooms in focus; the kitchen, the living room, and the bedroom. They state they turn the electric light on “less often” (100%) than in their former home, and they evaluate the light levels as “appropriate” (>72%) in the focus rooms .

The daylight levels in the house is rated either as “much higher” (88%) or as “higher” (12%) than their former home. They report that the daylight level is generally “appropriate” (>75%) in the kitchen, the living room, and the bedroom. There is a difference among the houses, where one house find there is “not enough daylight” in the kitchen, while another house evaluate the daylight level in the bedrooms as “too much daylight”. Between 89 and 100 % of the resident reported that they were “satisfied” or “very satisfied” with the daylight in the house in general and three rooms in focus; the kitchen, the living room, and the bedroom. They also state the windows is “about right” for all the rooms (>89%). Their preference for sunlight in the kitchen and living room is generally in the morning, in the afternoon and in the evening, while in the bedroom there is a clear preference for sunlight only in the morning. This could be the reason that they feel sometimes bothered by sunlight in the bedroom, while this is not an issue in the kitchen and living room.

View to the outside through the window is rated as “very important” (44%) or as “quite important” (50%). Between 72 and 83 % of the resident reported that they were “satisfied” or “very satisfied” with the view in the house in general and three rooms in focus; the kitchen, the living room, and the bedroom.

The residents state the location of the house on site is right and that the location in relation to daylight and sunlight is good. They do not find it too close to neighbours or roads. Their opinion if the house fit into the neighbourhood is “yes, very” or “yes, to some degree” (88%), and they have fairly clear opinion that house like this will be more common in the next 20 years. Their immediate impression of the house was futuristic, eco-consciousness and good architecture, but they find it possible to make architecturally attractive houses with PV Panels and solar thermal collectors, as well as an example of an architecturally attractive house.

Conclusion

The conclusion of the POE indicate, in general, that the families show high satisfaction with the indoor environment, that their expectations often are fulfilled, that house automation is acceptable, and being able to follow energy consumption and production increase awareness of their behavioural influence. Furthermore, combining excellent indoor environment with high quality homes, like Model Home 2020, give clear indication that the residents experience better health and better sleep quality, as well as having less sick days than when living in their former homes.

References

1. VELUX (2011). LichtAktiv Haus Booklet. http://www.velux.com/sustainable_living/demonstration_buildings/lichtaktiv_haus
2. VELUX (2011). Sunlighthouse Booklet. http://www.velux.com/sustainable_living/demonstration_buildings/sunlighthouse
3. VELUX (2011). Maison Air et Lumiére Booklet. http://www.maisonairetlumiere.fr/index.php/la-maison-air-et-lumiere/
4. VELUX (2011). CarbonLight homes Booklet. http://www.velux.com/sustainable_living/demonstration_buildings/carbonlighthomes
5. Hammershøj Olesen, G. G. (2014). *A Model for Enquiry of Sustainable Homes of Model Home 2020*. PhD Thesis, Aalborg University.

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Assessment of Occupant Satisfaction in Building Performance Evaluation based on Systematic Surveys

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Abstract: *In this paper a method for assessing the building performance from the occupants' perspective and their day-to-day experiences with comfort at office workspaces is introduced. The addressed comfort parameters were compatible with the description of the socio-cultural dimension of the German `Sustainable Building´ Quality Label for office and administrative buildings.*
Based on statistical analysis of surveys in 26 buildings an overall building index has been developed, which allows a quick evaluation of individual buildings or building stocks from a real estate manager's perspective. Beyond this index, differentiated information on perceived comfort can be used for a comprehensive building assessment supporting monitoring procedures and building performance optimization.
This method was applied in the German `Sustainable Building´ Quality Label process. All survey scores were transferred into scores used by the labeling system. One important result was that the numbers of dissatisfied persons appeared to be much higher in the surveys.

Key words: ***Occupant satisfaction, comfort, building performance evaluation, post occupancy evaluation, survey (POE)***

Introduction

With approx. 40% of the German primary energy consumption, buildings are of special interest in the context of sustainability. Driven by policy guidelines and interest of the real estate market, building performance evaluation is becoming a growing marketing factor. Offices represent an important work environment, thus building design should consider the needs of the occupants besides low energy strategies for heating, cooling, ventilation and lighting [1]. At present, little is known about approved criteria for the socio-cultural quality of buildings, whereas methods and tools for the monitoring of technical or economical characteristics are becoming more and more established. Particularly there is a lack of time and cost-effective procedures with regard to evaluation of comfort at workplaces.

To meet targets, Post-Occupancy Evaluation (POE) is a useful diagnostic tool and system which allows facility managers to identify and systematically evaluate critical aspects of building performance based on the employees' day-to-day experiences [2]. As complement to technical monitoring or lifecycle analyses, surveys have a great potential of gaining relevant feedback from the occupants as a basis for various improvements in energy efficiency regarding day-to-day operations. Experiences show that there is often a gap between the calculated and the metered energy consumption for a variety of reasons which can be assessed by continuous monitoring. This is expected as well in the wide field of comfort.

In Germany, a certification system for office and administration buildings has been launched. The Federal Ministry of Transport, Building and Urban Affairs (BMVBS) [3] in cooperation with the German Sustainability Buildings Society (DGNB) [4] developed a certification system for sustainable new office and administration buildings. Based on standards and calculated data topics such as ecology, economy, techniques, functionality and processes as well as the socio-cultural quality are considered. This topic includes comfort parameters like thermal, visual and aural comfort, air quality and options for occupants' control (e.g. operable windows) as well as safety and security aspects. The certification system has been expanded to existing buildings recently. It is intended to implement user surveys within a continuous monitoring procedure. The occupants' votes would allow a continuous check whether forecasted comfort parameters can be achieved in real building operation.

Main goals of the presented project were: (1) the development of an overall building index which allows the ranking of single buildings in comparison to a building stock on an aggregated level and (2) the development of a manageable (time- and cost-saving) and praxisoriented instrument with focus on occupant satisfaction.

Method

Building Sample and Participants: The field studies were conducted from 2008 to 2011. The range of the assessed 26 buildings includes different types, such as new, certified, old or refurbished buildings. The occupants were employees from civil service and the private sector (total of 2,832 datasets; the response rate averaged 46%).

Measures: Participants were asked to fill in a questionnaire which was provided as paper-pencil version (2008 and 2009) as well as an online survey (2010 and 2011). The questionnaire was developed in accordance to frameworks from environmental psychology, findings in the field of the sick-buildings-syndrome [5, 6] and the questionnaire of the Center for the Built Environment, University of California, Berkeley [7]. Besides demographic information (e.g. gender, age) and background information (e.g. orientation of the office, distance to window) the items focus the degree of satisfaction with the ambient comfort parameters in the workspace such as (1) temperature, (2) light (natural and artificial light, shades/blinds), (3) air quality, (4) acoustics/noise, (5) furniture/layout and (6) spatial conditions (e.g. amount of space, privacy). Additionally, items were added which broach the issue of (7) the entire building (e.g. restrooms, conference rooms) and which coincide with the criteria for the German certificate (e.g. safety, security). Each of the 7 main comfort parameters includes a subset of items and the accordant concluding question `Overall, how satisfied are you with … in your workspace?´. Answers concerning the degree of satisfaction were coded continuously on a 5-point-Likert-scale from very dissatisfied (-2) to very satisfied (+2).

Statistical Analyses: Different statistical procedures were applied to prove if there is statistical evidence for an overall building index: (a) Factor Analysis, (b) Principal Component Analysis (PCA) with optimal scaling and (c) Correspondence Analysis. The aim was to prove if large sets of variables could be reduced to one factor by aggregating individual-level data to

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construct measures for units at a higher level. The applied software was PASW (Predictive Analysis SoftWare) and SPSS 18 (Statistical Package for the Social Sciences).

Results
Statistical Analyses: After having tested that reliability for the 7 indicator subsets is given (Cronbachs alpha for winter survey = .84, Cronbachs alpha for summer survey = .81) all 7 concluding `Overall…´-questions were comprised in the analysis to test for the underlying dimensions in the data. The computations by PCA revealed a one-factor solution with high positive loadings for all seven indicators (> 0,7) and an eigenvalue greater 1 (3,856). The results were confirmed by correspondence analyses (for a more detailed description see [8, 9]). Table 1 shows results of the factor analysis.

Table 1: Component loadings from factor analyses for comfort parameters. Component loadings: > 0, 7 = very high, 0, 5 - 0, 69 high, 0, 3-0, 49 poor, < 0, 3 very poor. Sample: 26 buildings.

Comfort parameter	**Winter Survey** $N = 1{,}578$	**Summer Survey** $N = 1{,}254$
Overall, how satisfied are you with **the building**?	.72	.77
Overall, how satisfied are you with **furniture/layout** in your workspace?	.70	.70
Overall, how satisfied are you with **spatial conditions** in your workspace?	.75	.81
Overall, how satisfied are you with **acoustics/noise** in your workspace?	.74	.77
Overall, how satisfied are you with **air quality** in your workspace?	.69	.71
Overall, how satisfied are you with **temperature** in your workspace?	.74	.73
Overall, how satisfied are you with **lighting conditions** in your workspace?	.70	.56

All variables have very high or high loadings. A high value for the Kaiser-Meyer-Olkinstatistics (winter survey: KMO = .84, x2 = 3318, p < .001, eigenvalue 3,614, other eigenvalues < 1; summer survey: KMO = .84, x2 = 1423, p < .001, eigenvalue 3,652, other eigenvalues < 1) shows that homogeneity in the data is given. An overall index could be developed (Figure 1) which is applicable for the survey instrument **INKA** (**I**nstrument für **N**utzerbefragungen zum **K**omfort am **A**rbeitsplatz). The index results as the mean score of the 7 indicators (Figure 2).

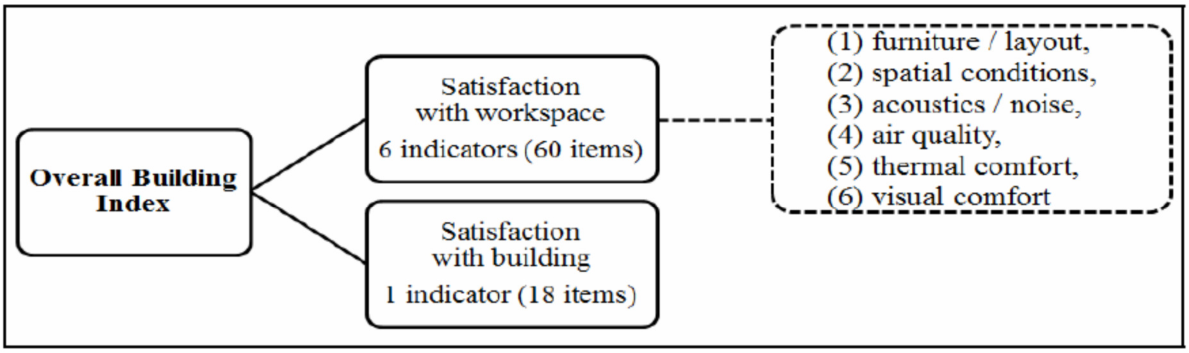

Figure 1: Facets of the final `Overall Building Index´

Instrument ***INKA***: For wider application in practice a time- and cost-effective survey instrument was developed including a computer-based questionnaire and an easy to handle automatic evaluation procedure for the Facility Management staff respectively personnel from the real estate market. The given information includes a report sheet showing the index, mean values for comfort parameters (overall-questions) concerning the workspace and the building. Additionally, the frequency distribution for the comfort parameters is given based on three categories (very dissatisfied/dissatisfied, neutral and satisfied/very satisfied). On a general level, the overall building index and the mean scores for comfort parameters serve as benchmarks with respect to a comparison of larger building stocks and to screen monitoring processes regarding occupants' feedback in single buildings (Figure 2).

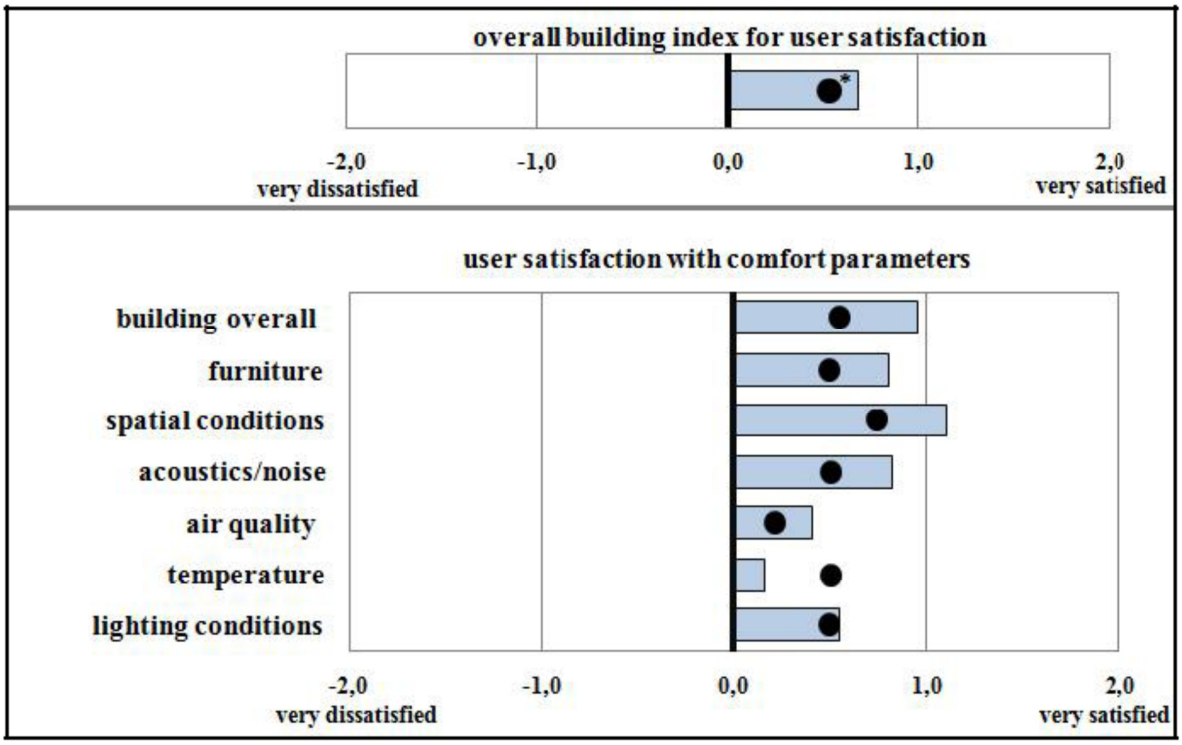

Figure 2: Results for a building with certificate in `gold´ (bars) in comparison to a sample of 26 buildings (N =1,578) assessed in winter seasons 2008 to 2011.*

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The graph shows results for a building with a `gold´ certificate based on the German certification system. In comparison to the scores of the sample most comfort parameters in this building are in line or even better, but obviously the occupants experienced less comfort with temperature. This information is helpful for the Facility Management staff either for a portfolio analysis or for planning interventions. The benefit of occupant surveys as part of the new German certification system for existing buildings is to compare the results to the predicted outcome for the socio-cultural quality based on plans, standards and audits and to detect the potential for optimization (Table 2).

Table 2: Ratings for the building with `gold´ certificate: predicted comfort from certification procedure (degree of compliance) and results from occupant surveys (N = 115) regarding comfort parameters (1survey in 2008, other comfort data derive from a survey in winter 2009.

Comfort parameters	Predicted comfort from certification system	Experienced comfort based on occupant survey	
		satisfied/very satisfied	dissatisfied/very dissatisfied
thermal comfort in winter	100%	43%	31%
thermal comfort in summer[1]	100%	45%	26%
air quality	100%	50%	16%
acoustics/noise	100%	66%	6%
visual comfort	85%	73%	18%

Even if it is not realistic to obtain 100% satisfaction for comfort by subjective ratings, the outcome for this building shows an enormous gap between the predicted comfort and the results from the occupant surveys concerning the indoor environment conditions `temperature`, `air quality´ and `acoustics/noise´. Values for visual comfort are more congruent, maybe due to the fact that during the certification procedure the architectural feature `atrium´ was taken into account which resulted in a reduced degree of compliance.

Discussion

The main scientific objective of the project was to develop an overall building index for comfort assessment. A result from statistical analysis was that general satisfaction with comfort at workspaces and in the building can be represented by one factor. The overall satisfaction can be expressed by an overall building index based on simply summed mean scores from the included comfort parameters. This score can be expressed comprehensible by the same codes used in the questionnaire (very dissatisfied (-2) to very satisfied (+2)) and therefore needs no further transformation into threshold values.

The high attractiveness of an `overall building index´ obtained from surveys expresses itself by the possibility of a quick ranking of buildings in terms of occupant satisfaction. With regard to portfolio analyses the index can be used as a first orientation in the sense of a screening instrument for investors or owners. An index has limitations as well. Buildings are complex due to e.g. architectural features, functionalities, and maintenance Thus an index should not replace an in-depth evaluation in buildings to detect the potential for optimization. Furthermore, when considering comfort as `a matter of culture and convention´ [10], changes in importance of comfort parameters over time respectively generations are expectable, and so instruments for measuring subjective issues should be well defined and adjusted for its scope. The discussed aspects illustrate the complexity of the social issues in the field of building performance and the challenge of translating social reality into scores. Another limitation to the findings could be the sample size. The acquisition of buildings is often complicated and troublesome for a variety of reasons.

The database for occupant surveys in Germany is still too small to define threshold values or standards for the socio-cultural quality (presuming this is basically a realistic approach). For this a standardised sample would be required. Nevertheless, a continuous assessment of occupants' feedback seems to be a useful part for evaluating the sustainability of buildings in certification systems. With respect to the demand of energetic refurbishments, the huge number of existing office buildings is a crucial issue also in the field of comfort at workspaces. Besides energy efficiency and optimal building operation a great potential lies in occupants' behaviour. The development and evaluation of smart feedback-systems which enable occupants to understand and to react properly to the energy concept of a building are a future challenge in the field of post-occupancy evaluation as well as in the long run for updating certification systems.

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References

[1] Voss, K., Löhnert, G., Herkel, S., Wagner, A., Wambsganß, M. (Hrsg.): Bürogebäude mit Zukunft. Konzepte, Analysen, Erfahrungen. solarpraxis, Berlin, 2006.

[2] Preiser, W. F. E., Schramm, U.: A conceptual framework for building performance evaluation. In W. F. Preiser, J. C. Vischer (Eds.) Assessing Building Performance, pp 15-26. Elsevier, Oxford, 2005.

[3] Bundesministerium für Bau-, Stadt- und Raumentwicklung: Leitfaden Nachhaltiges Bauen, 2. Auflage. BMVBS, Berlin, 2011.

[4] Deutsche Gesellschaft für Nachhaltiges Bauen e.V.: Excellence defined. Sustainable Building with a Systems Approach. DGNB, Stuttgart, 2010.

[5] Gifford, R.: Environmental Psychology: Principles and Practice (2th Ed.). Optimal books, Colville, WA. 2002.

[6] Bischof, W., Bullinger-Naber, M., Kruppa, B., Müller, H. B. Schwab, R.: Expositionen und gesundheitliche Beeinträchtigungen in Bürogebäuden - Ergebnisse des ProKlimAProjektes. Fraunhofer IRB, Stuttgart, 2003.

[7] www.cbe.berkeley.edu

[8] Schakib-Ekbatan, K., Wagner, A., Lussac, C.: Occupant satisfaction as an indicator for the socio-cultural dimension of sustainable office buildings – Development of an overall building index. Proc. of Conference: Adapting to Change: New Thinking on Comfort, Windsor, 2010 [http://nceub.org.uk].

[9] Wagner, A., Schakib-Ekbatan, K.: Nutzerzufriedenheit als ein Indikator für die Beschreibung und Beurteilung der sozialen Dimension der Nachhaltigkeit. Fraunhofer IRB, Stuttgart, 2010.

[10] Chappells, H., Shove, E.: Debating the future of comfort: Environmental sustainability, energy consumption and the indoor environment. Building Research & Information, 33(1), pp 32-40, 2005.

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Using the EduTool:IEQ to evaluate the IEQ performance inside classrooms

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The EduTool:IEQ is a post occupancy evaluation tool used for assessing the indoor environment quality (IEQ) inside primary and middle school classrooms. The quality of the indoor environment inside classrooms is an important issue, as poor IEQ can trigger health and learning difficulties for students. This paper describes the methodology used by the EduTool:IEQ to assess the IEQ performance inside primary and middle school classrooms. The four stages involved in undertaking an assessment using the EduTool:IEQ are described. Particular attention is given to describing why the EduTool:IEQ is an important tool for design professionals. The paper concludes with a discussion of three case studies. The case studies demonstrate the feasibility of using the EduTool:IEQ Info-graphic to communicate succinct information about IEQ performance to design professionals. This information could enable targeted remedial works to be undertaken, to improve IEQ performance.

Indoor Environment Quality, Classroom, Design Professional, Info-graphic, Health

Introduction

The *EduTool:IEQ* is a new post occupancy evaluation (POE) tool, developed to provide design professionals with succinct and targeted information about the indoor environment quality (IEQ) inside primary and middle school classrooms. POE "systematically evaluates the performance of buildings after they have been built and occupied"[1]. Guiding the POE process using *tools* can regulate the feedback loops used to inform the future work of design professionals [2]. In this paper 'design professionals' is the term used to describe the broad group of professionals involved in designing and building classrooms. This may include architects, interior designers, educational facility planners, engineers or builders.

Classrooms are complex environments overlaid with environmental, pedagogical, socio-cultural, curricular, motivational, and socio-economic issues [3]. IEQ is an environmental issue concerned with the levels of lighting, thermal comfort, air quality and acoustics inside classrooms [4, 5]. The IEQ performance inside a classroom can trigger health and learning

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difficulties for students [7, 8, 9]. Young students are particularly vulnerable because of the dynamic state of growth their bodies and minds are undergoing [10].

The *EduTool:IEQ* was developed as part of a PhD in Architecture [11]. A review of existing POE tools revealed that there is not an existing POE tool for objectively evaluating the IEQ performance inside primary and middle school classrooms, against the needs of young students' and educators' to engage in effective teaching and learning [4, 12]. Therefore the development of the *EduTool:IEQ* fills a gap in knowledge.

This paper begins with justification for the research, using a summary of the literature to describe why a new POE tool for evaluating IEQ performance inside classrooms is necessary. This is followed by a description of the four stages involved in using the *EduTool:IEQ*. The stages are data collection, data processing and analysis, and data reporting. The paper concludes with an overview of three case studies, to demonstrate how the findings from an evaluation may be communicated to design professionals across three scales of information. There was not the scope in this paper to describe the research that lead to the development of the EduTool:IEQ. These details can be found in existing publication [11,13].

Justification for the research

Students can spend up to 15 000 hours at school, during their formative years and 90% of their time inside classrooms [14, 15, 16]. Experts in the field of education and training argue that the quality of the environments in which students learn, can have positive and negative impacts on how *well* they learn [7, 8, 9, 17, 18]. Effective teaching and learning is important, because the level of skills and knowledge that students gain at school can influence the type of opportunities and 'quality of life' they have access to as adults [10, 19].

Young students attending primary and middle schools are particularly vulnerable inside classrooms with poor IEQ. This is because – unlike older students and adults –the bodies and minds of younger students are still in a "dynamic state of growth" and high concentrations of environmental contaminants (often found in the air) can cause irreversible damage to their nervous, immune, respiratory, endocrine, reproductive and digestive systems [10]. Younger students are also in the process of developing reading, writing and listening skills. These skills form the foundations of comprehension, which is an important life-skill used to "interpret, integrate, critique, infer, analyse, connect and evaluate ideas" [20]. There are examples in the literature, which suggest that classrooms with poor IEQ can slow student progress in learning comprehension [7, 8, 17, 21, 22]. Therefore in order to reach their full potential, students need to learn inside classrooms with good IEQ.

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IEQ performance inside a classroom can be the product of how a building has been designed, constructed, maintained and/or operated by the occupants [23]. Design professionals can have a hand in improving the IEQ performance of classrooms through making well-informed decisions during the design phase. A new POE tool that provides design professionals with feedback about the IEQ performance inside their buildings, may broaden their understanding of the specific impact that design decision can have on IEQ [2]. The assertion that design professionals need to 'broaden' their understanding of IEQ comes from opinions expressed in the literature, about the scope that exists to make improvements to how IEQ education is taught to architecture and engineering students at tertiary institutions [24, 25, 26].

Methodology

IEQ is a system that is informed by sub-systems and components [25]. The sub-systems and components that are of interest to the *EduTool:IEQ* are those with the greatest potential to impact on effective teaching and learning, inside primary and middle school classrooms. Through a literature review, acoustics, thermal comfort, air quality and lighting were chosen for inclusion in the *EduTool:IEQ*. Other sub-systems such as aesthetics were excluded, because they cannot be evaluated objectively [27]. In addition, there are other existing POE tools (for use in schools), which investigate the impact of aesthetics, space planning and ergonomics on effective teaching and learning [11, 28].

The literature review identified over 40 components – specific to acoustics, thermal comfort, air quality and lighting – with the potential to impact on effective teaching and learning [11]. Using causality theory (and causal chaining) this group of components was reduced to 16, with four components chosen for each sub-system [11, 17]. There is no hierarchy amongst these components. This decision was influenced by arguments made in the literature, about the need for design professionals to conduct their practice with a whole building approach, which "takes full advantage of the symbiotic nature of design so that the design elements work to reinforce each other and thereby maximise the ability of the overall building design to fulfil its design objectives effectively and with greater efficiency and also lower capital and operating costs"[6].

The *EduTool:IEQ* is designed to communicate to design professionals information about IEQ performance inside a classroom, across three scales. At the macro scale a design professional may focus on overall IEQ; at the mezzo scale they may focus on the performance of the sub-systems; and at the micro scale they may focus on the performance of individual components. This level of analysis is facilitated through how the *EduTool:IEQ* has been designed for use. An IEQ assessment conducted using the EduTool:IEQ involves four unique stages.

The first stage is data collection. The EduTool:IEQ prescribes the objective and descriptive methods that an assessor should use to collect data about the 16 components. Objective data is collected using environmental monitoring equipment. Below is a summary, which describes how data about the 16 components is collected using environmental monitoring equipment:

'Continuous samples' may be used to generate hourly, daily, weekly, monthly or seasonal profiles about the performance of an IEQ component. The *EduTool:IEQ* uses continuous sampling to evaluate: ambient temperature, relative humidity, carbon dioxide and vertical illumination. During the 12 month-monitoring period, data about these four IEQ components was continuously collected at 15minute time-intervals from a fixed location in the classrooms.

'Periodic spot samples' may be used to generate weekly, monthly or seasonal profiles about the performance of an IEQ component. The *EduTool:IEQ* uses periodic sampling to evaluate: background and mechanical noise, signal to noise ratio (SNR), daylight and horizontal illuminance, lighting control, radiant floor temperature and airflow. During the 12 month-monitoring period, data was collected seasonally about these eight IEQ components at multiple, uniformly distributed locations in the classrooms (using 1500mm grid) [29].

'Once off spot samples' may be used to generate a 'worst-case-scenario' (per season or annum) about the performance of an IEQ component. The *EduTool:IEQ* uses once off spot samples to evaluate: total volatile organic compounds (TVOC), particular matter (PM10), airborne microbial and reverberation times. During the 12 month-monitoring period, data was collected about these four IEQ characteristics from a fixed location in the classrooms. The timing of the data collection corresponded with conditions equal to worst-case scenarios [29].

Descriptive data is collected using overt observation about the physical conditions inside the classroom. Here the assessor needs to make value judgments about cleanliness and efficiency of operating systems (in particular lighting and HVAC), along with observations about how the occupants' behaviour may have influenced the objective data collected.

In the second stage the data collected about the 16 IEQ components is processed, however only the objective data is used. Processing the data involves calculating a single quantitative result (QR) for each of the 16 components. In order to do this, it is first necessary to define the 'period of occupancy' under investigation. The QR is a calculation that takes the average of all the data points collected during the period of occupancy. Inside the 10 classrooms evaluated with the *Edutool:IEQ*, the period of occupancy was: *'school hours' (7:30am to 4:29pm) on 'weekdays' (Monday to Friday) during 'term time'*. For each component, two

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QRs were calculated. One indicative of performance in winter and the other was indicative of the performance for summer. Having two QRs allows for comparisons to be made.

In Stage 3 the QRs calculated for each component are analysed, to determine (in qualitative terms) their level of performance. To do this the researcher developed 'scaling tables', which are type of environmental index that quantifies and numerically benchmarks the QR against different levels of practice. The scaling tables are a culmination of the performance-based advice published about IEQ in over 70 sources[1]. A QR awarded a score of 10/10 is an example of 'next practice' (which is a level of performance that goes beyond current best practice). A QR awarded a score of 1/10 is an example of 'unacceptable practice'. A QR awarded a score of 5/10 achieves the minimum required level of practice (Table 1).

Score	Performance thresholds
10	Achieves Next Practice
9	Achieves Best Practice
8	Achieves Excellent Practice
7	Achieves Good Practice
6	Achieves Acceptable Practice
5	Achieves Minimum Practice
4	Below Minimum Practice
3	Unsatisfactory Practice
2	Problematic Practice
1	Unacceptable Practice
0	No data set

Score	Range Carbon dioxide levels (ppm)
10	0.01 - 600
9	601 - 700
8	701 - 800
7	801 - 900
6	901 - 1000
5	1001 - 1100
4	1101 - 1200
3	1201 - 1300
2	1301 - 1400
1	1401+
0	No data

Table 1 is an example of the scaling table for carbon dioxide.

The decision to condense the performance of each IEQ component into a single number was based on the widespread adoption of green building rating tools (LEED, BREAAM and NABERS). These use reward systems that are logical, intuitive and non-industry specific to rate building performance. The overall legibility of these scales makes the tools attractive to clients and designers [5]. They create opportunities for comparisons to be made, between buildings, from which conclusions may be drawn about the effectiveness of design solutions.

[1]. The sources were either user-manuals of building evaluation tools (LEED, BREEAM, Green Star), national and international building standards (ISO, AS, ANSI etc) and building guidelines.

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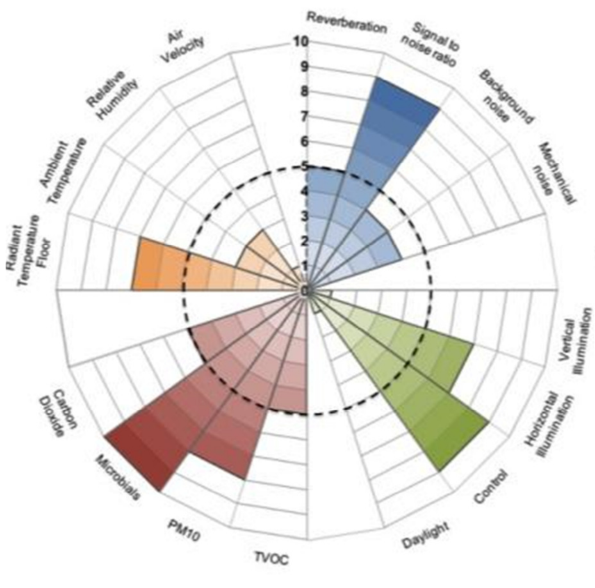
In Stage 4, the results of the evaluation are reported using the *EduTool:IEQ Info-graphic*, which is a data visualisation method. Designer professionals are often more attracted to information that is communicated graphically, than textually or numerically [30]. Therefore, presenting technical information using data visualisation complements the natural tendencies of design professionals [30]. In the theory on info-graphics, the kind of shapes that are generated using numbers can have a greater impact on their audience compared with numbers alone. This is because shapes are able to be "experienced rather than read" [31].

The three scales of information summarised above (macro, mezzo and micro) are present in the *EduTool:IEQ Info-graphic*. At the macro scale, the uniformity and total number of shaded cells can be used to explain the overall IEQ performance inside the classroom. At the mezzo level, the performance of the four sub-systems can be individually assessed and compared. At the micro level it is possible to investigate the performance of individual components. The dashed ring in the centre of the info-graphic is the threshold of minimum practice. From interpreting the *EduTool:IEQ Info-graphic* and the descriptive data (collected in Stage 1), a design professional may use deductive reasoning to identify the cause of poor IEQ performance inside the classroom and may be able to recommend the required remedial work.

Figure 1a: WET SEASON IEQ (Tropical climate)

Figure 1b: DRY SEASON IEQ (Tropical climate)



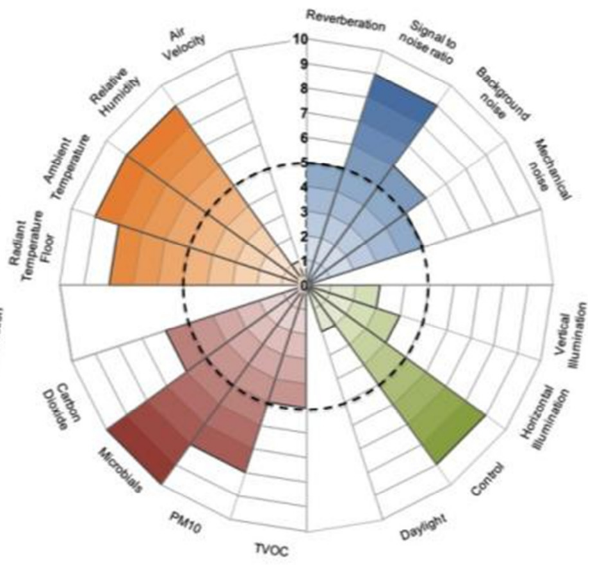


Figure 2a: SUMMER IEQ (Arid climate) Figure 3a: WINTER IEQ (Arid climate)

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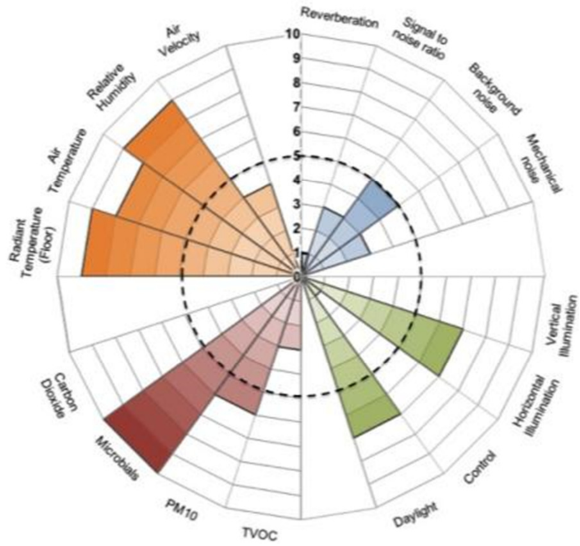


Figure 3a: SUMMER IEQ (Temperate climate)

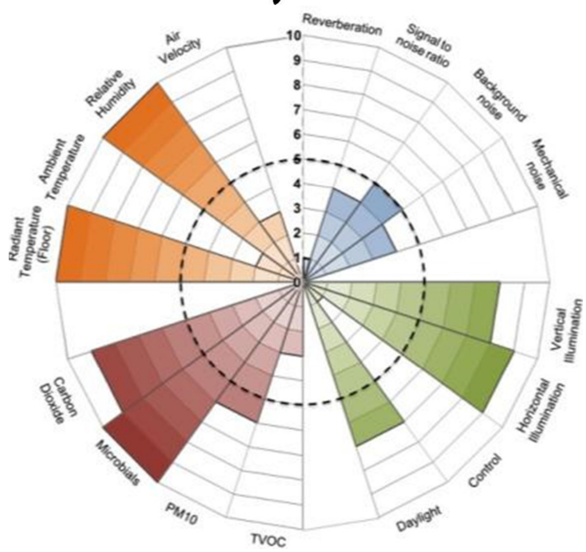
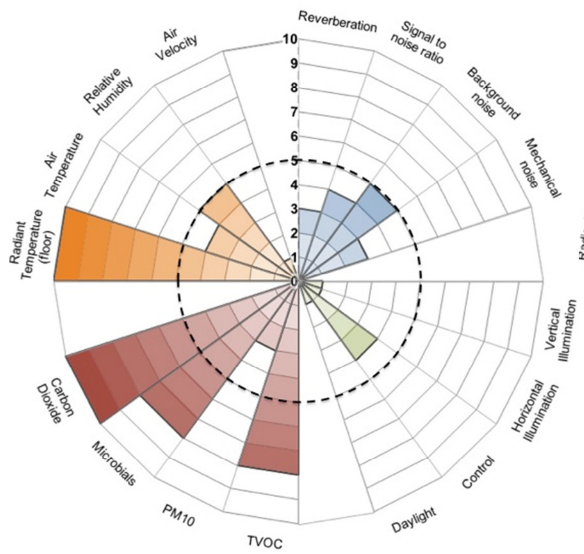
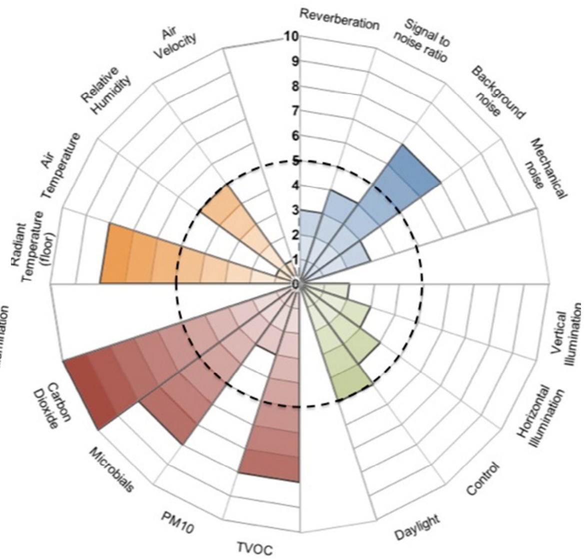


Figure 3b: WINTER IEQ (Temperate climate)





Figures 1, 2 & 3: IEQ performance in three case studies across two opposing seasons shown with info-graphics.

Clockwise: Reverberation; SNR, Background noise; Mechanical noise; V.Illumination, H.Illumination, Control, Daylight, TVOC, PM10, Microbial, CO_2, Radiant Temp, Ambient Temp, Relative Humidity, and Airflow.

Case studies and key outcomes

Figures 1a & 1b; 2a & 2b; and 3a & 3b are examples of the *Edutool:IEQ Info-graphic.* They display the results from IEQ assessments undertaken in three case studies. There is not the scope in this paper to provide a detailed analysis of the results. These examples demonstrate how the *EduTool:IEQ Info-graphic* can be used to communicate information about the IEQ performance inside classrooms across the macro, mezzo and micro scales.

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- At the macro scale, the occupants of the tropical classroom experienced the most favorable IEQ, during the dry season (Figure 1b). In contrast, the occupants inside the temperate classroom experienced the least favorable IEQ during summer (Figure 3a).

- At the mezzo scale, air quality was a sub-system that performed consistently well. In contrast, acoustics was a sub-system that regularly performed poorly. The occupants of the tropical classroom experienced the most favourable acoustics during the dry season. The classroom acoustics were less favourable in the wet season due to the monsoonal rains, which increased the overall levels of background and mechanical noise inside the classroom. The acoustical performance inside the tropical classroom may be attributed to the use of acoustic treatments on the walls and floor. In contrast the arid classroom had no acoustical treatment and this is reflected in the results of the *Edutool:IEQ Info-graphic*.

- At the micro scale, airflow was one of the components that regularly performed poorly. What cannot be determined from the *Edutool:IEQ Info-graphic* was the cause (i.e. too much or tool little airflow). This highlights the important role of descriptive data. In the tropical classroom, descriptive data explains that the poor performance of airflow is caused by the absence of ceiling fans and operable windows. Air diffusers in the ceiling provide refrigerated cooling. Approximately 40% of the students (when seated at their desks) experience airflow equal to 0.1m/s, while the required amount is 0.3m/s. In an interview, the teacher commented that she felt "very little breeze from the air conditioning vents", which made the classroom feel "quite warm and stuffy in the wet season".

- The occupants inside the temperate classroom experience problems with glare, as a result of large areas of window glazing (equal to 42% of the floor area). The occupants cannot control the amount of daylight entering the classroom because the operable blinds were broken. In contrast, the occupants of the tropical classroom have a high level of control over the lighting levels inside the classroom. This is in part because there is less access to daylight (with window glazing equal to 11% of the floor area). While the design of the classroom meets the code requirements for daylight access, the window treatments prevent the required levels of daylight (as per the standards) from entering the classrooms.

Conclusion

This paper describes the IEQ performance inside classrooms as being a trigger for health and learning difficulties for students. Design professionals can have a hand in improving the IEQ performance inside classrooms through making well-informed design decisions, which are informed by the feedback loops provided by POE tools. The *EduTool:IEQ* is new POE tool that communicates succinct information to design professionals about the IEQ inside

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classrooms. The information is 'succinct' because it communicates the findings across three scales. This paper describes the methodology of the *EduTool:IEQ* and briefly discusses the findings from three case studies, to demonstrate the type of information design professionals can access about classroom IEQ. The findings provided by the *EduTool:IEQ* can enable targeted remedial works, that will improve the classroom IEQ, to be undertaken.

References

1.Federal Facilities Council. (2001). *Learning from our Buildings. A State-of-the-Practice Summary of Post-Occupancy Evaluation*, National Academy Press, Washington, DC (p.42)

2. Baker, L. (2011). *What School Buildings Can Teach Us: Post-Occupancy Evaluation.* MS Thesis, Dept. of Architecture. University of California, Berkeley.

3.Higgins, S., Hall, E., Wall, K., Woolner, P., & McCaughey, C. (2005) *The Impact of School Environments: A literature review*, The Design Council, accessed www.design-council.org.uk/ (1/7/2009)

4.Catalina T. & Iordache, V. (2012). IEQ Assessment on Schools in the Design Stage, in *Building and Environment,* Elsevier Science Direct, Vol. 49, pp. 129-140.

5.Heinzerling, D. (2012). *Commercial Building Indoor Environmental Quality Evaluation: Methods and Tools,* M.S. thesis, Department of Architecture, University of California, Berkeley.

6.ASHRAE. (2009). Indoor Air Quality Guide: Best Practice for Design, Construction and Commissioning, accessed www.ashrae.org/resources--publications/bookstore/indoor-air-quality-guide (3/4/2011).

7.Daisy, J.M., Angell, W.J. a& Apte, M.G. (2003) Indoor air quality, ventilation and health symptoms in schools: An analysis of existing information, in *Indoor Air* 13:53-64.

8.Earthman. G.I. (2004) *Prioritization of 31 criteria for school building adequacy.*

9. Healthy Schools Network. (2013) *Towards Health Schools*, accessed www.healthyschools.org (11/12/2013)

10.World Health Organisation. (2006). *The Physical School Environment*, accessed www.who.int/school_youth_health/media/en/physical_sch_environment.pdf (9/10/2013).

11.Soccio, P. (2014). Communicating succinct and targeted information to design professionals about the indoor environment quality inside Australian primary and middle school classrooms, Unpublished PhD, The University of Melbourne, Melbourne

12.Luther, M. (2013). Review of measurements in schools to improve IEQ, Paper presented at *10th International Conference of Healthy Buildings*, Queensland University of Technology, Brisbane, Queensland

13.Soccio, P. (2014), The EduTool:IEQ – a new post occupancy evaluation tool for communicating to building designers information about the indoor environment quality inside classrooms, Paper accepted for presentation at the *13th International Conference on Indoor Air and Climate,* University of Hong Kong, Hong Kong, July 7-12

14.Johnson, P. & Kritsonis, W. (2010). 'Greener Schools, Greater Learning, and the LEED Value, in *Doctoral Forum', National Journal for publishing and mentoring Doctorial student research,* vol.7, no.1

15.Rutter, M. (1979). *15,000 hours: Secondary schools and their effect on children*, Open Books

16.US EPA. (2008). Portable Classrooms, accessed www.epa.gov/iaq/schooldesign/portables.html (29/10/2008).

17. Mendell, M. & Heath, G. (2005). Do indoor pollutants and thermal conditions in schools influence student performance? A critical review of the literature, in *Indoor Air,* vol. 15, pp. 27-52

18. Wakefield, J. (2002). Learning the Hard Way: The poor environment of America's Schools, in *Environmental Health Perspectives,* vol. 110, no. 6, pp. 298-305

19. OECD. (2012). *Equity and Quality in Education: Supporting Disadvantaged Students and Schools*, accessed at www.oecd.org/education/school/50293148.pdf (5/6/13)

20. NSW Department of Education and Training. (2010) Website, accessed at www.dec.nsw.gov.au (4/5/2014)

21.Evans, G, Maxwell, L. (1997). Chronic noise exposure and reading deficits: The mediating effects of language acquisition, in *Environment and Behavior,* vol.29 no.5, pp. 638-656

22.Hygge, S. (2003). Classroom experiments on the effects of different noise sources and sound levels on long-term recall and recognition in children, in *Applied Cognitive Psychology*. 17:895-914.

23.Vittori, G. (2002). Green and Healthy Buildings for the Healthcare Industry White Paper, in *CleanMed,* Center for Maximum Potential Building Systems, Austin

24.ASHRAE, (2010). *Research Strategic Plan 2010-2015:Navigation for a Sustainable Future*, accessed www.ashrae.org (11/9/2013).

25.Bluyssen, PM. (2013) *Understanding the indoor environment* [Inaugural speech], Faculty of Architecture, Delft University of Technology, 22 May 2013.

26.Loftness, V., Lam, K.P., Hartkopf, V. (2007). Education and environmental performance-based design: a Carnegie Mellon perspective, in *Building Research & Information*, 33(2), pp 196-203.

27.Lee, Y, Guerin, D. (2009). Indoor environmental quality related to occupant satisfaction and performance in LEED-certified buildings, in *Journal of Indoor & Built Environment,* vol. 18**,** no.4, pp. 293–300

28. Cleveland, B., & Fisher, K., (2011*), The evaluation of physical learning environments: a critical review of the literature*, LEaRN Working Paper, The University of Melbourne

29.IPMVP. (2002). *International Performance Measurement and Verifiaction Protocol Volume II: Concepts and Practices for Improved Indoor Environment Quality*, IPMVP Inc

30.Lawson, B. (2006), *How Designers Think: The Design Process Demystified,* London: Architectural Press.

31.Sullivan, P., Case, D., Bolz, N., Mijksenaar, P., Ward, S., & Burkhardt F. W. (1996). *Information Design and Infographics*. Netherlands: European Institute for Research and Development of Graphic Communication.

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Session 10:

Where should energy renovation reach up to? (I)

Chairperson:

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Method to develop cost-effective studies of energy efficiency measures for Mediterranean residential existing buildings with multi-criteria optimization.

Speakers:
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Abstract: *The present paper describes a method to develop cost-effective studies of energy efficiency measures for residential building renovation. The method allows a detailed characterization of the energy consumption of buildings, applying energy efficiency measures and evaluating the thermal comfort and the cost-effectiveness of the proposed measures. Dynamic simulations with TRNSYS are used for the building simulation, with a detailed characterization of the interaction between climate-building-user. A multi-criteria optimization is done with ZEUS, in order to develop the thermal comfort evaluation and the cost-effective study of the energy efficiency measures. The method includes innovative aspects: two-step optimization considering comfort, energy and economic parameters; the use of stochastic profiles for the user behavior; the building characteristics updated with survey data; the economic evaluation and the cost-effective analysis are done as defined by the European regulation; to prioritize the passive measures rather than the active ones, guaranteeing the thermal comfort of the users.*

Key words: Residential building renovation, energy efficiency measures, cost-effective evaluation, multi-criteria optimization, stochastic user behavior, thermal comfort

Introduction

Within the European regulatory framework and the agreement signed by Member States, the states and regions have an essential role in decision-making to reach the 20/20/20 targets, applying the Energy Performance of Building Directive (EPBD, recast) [1] and the Energy Efficiency Directive [2]. As the existing residential sector is one with greater potential for energy saving is one which faces more barriers, too. In Catalonia, the energy renovation rate is around 0.2% dwellings per year [3], which represents a low fraction of the building stock. Promotion of the energy renovation of buildings is needed, being sure that available measures are cost-effective in a long term as well as they improve the comfort of the users. In consequence, detailed studies are needed to consider all the aspects that have influence in the

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energy consumption of buildings: climate, building characteristics, users' characteristics and their behavior, the performance of the energy systems and appliances, and their use.

This paper describes a detailed and integrated method that allows the characterization of the energy consumption of buildings, to apply energy efficiency measures and to evaluate the thermal comfort and the cost-effectiveness of proposed measures.

Description of the method

The main objective of the proposed method is to define a complete process for carrying out cost-effective studies of energy efficiency measures in existing buildings. The method is divided into four steps, as the Figure 1 shows: building simulation, comfort evaluation, energy efficiency measures and cost-optimal analysis.

In the building simulation process is where the energy simulation is done. Here, the building and its interaction with the users is characterized in a detailed way using TRNSYS [4]. The energy consumption is obtained for the base case (the existing building) and for the building with the energy efficiency measures. In the simulation process, also the comfort and the economic evaluation are done.

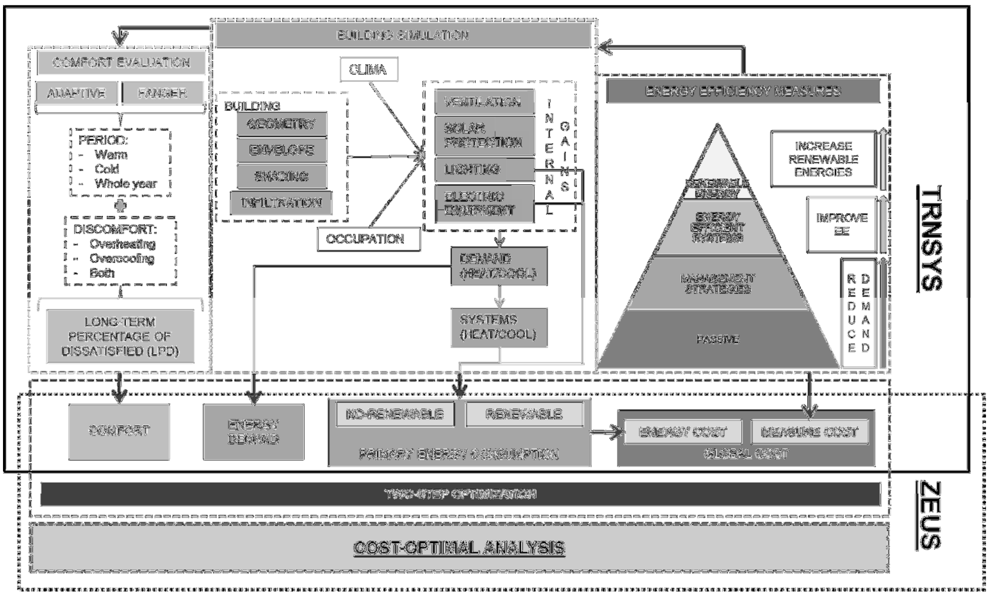

Figure 1 Overview of the method proposed for the Cost-Optimal Analysis

Finally, the optimization process is divided in two steps: passive and active optimization. In the first optimization, the objective is to obtain cost-effective passive measures that provide a better thermal comfort without the use of active systems. Afterwards, with the best solutions, the active measures are applied in order to consider heating and cooling systems, and renewable energy systems. In that case, the optimization takes into consideration the energy consumption, the global costs and also the thermal comfort of the users. The software used to carry out the optimization is ZEUS (Zero Emissions Urban Simulator) [5] developed by InLab FIB (Politechnical University of Catalonia, UPC).

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Detailed building simulation

Building features

The building geometry (Figure 2) is introduced in the simulation by a multizone 3D model using the plugin Trnsys3D for Google SketchUp. In order to simulate the building with more detail, only two floors are included: the standard floor and the under roof floor. Then, each dwelling is divided following two zonification criteria: night and day use, and orientation. The building model includes the external environment and their corresponding shadings.

The envelope materials are defined depending on the year of construction. This information has been obtained from previous studies [6, 7]. In addition, coldbridges are considered in façade, roof, windows and columns.

To finish the building characterization, a detailed model of infiltration is included [8], where the tightness of the construction is considered. The method allows the use measurement data obtained from experimental studies and blower door tests [9, 10].

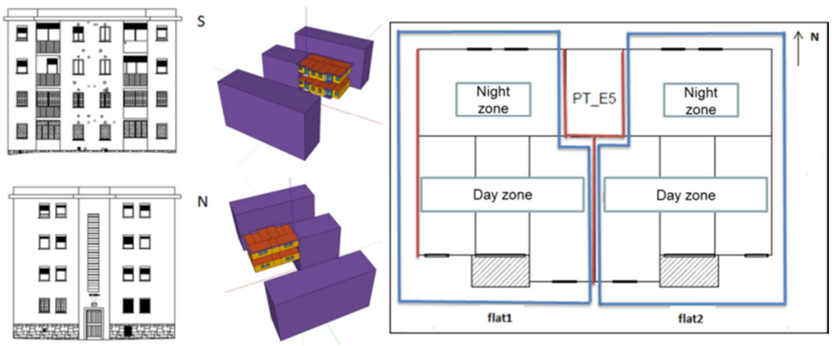

Figure 2 Example of building geometry. Left: North and south façade. Center: 3D model in Google SketchUp: standard floor, under roof floor and external environment. Right: dwelling zonification.

Occupancy and their use of the building

In the present model, the occupancy is the main driver of the use of the building (heating and cooling systems, natural ventilation, solar protections, domestic hot water (DHW), lighting and appliances). For that reason a stochastic profile is included in the simulation, in order to use a more realistic behavior of the users. Depending on the building typology a type of family is chosen: 1 or 2 adults, 3 or more adults, and 1 adult with child. This profile is obtained from the Time Use Data surveys of Spain (TUD) [11], and allows assigning three states of each occupant (**¡Error! No se encuentra el origen de la referencia.**): outside of home, passive at home, and active at home.

The first effect of the occupancy is the internal gains that it produces. Then, the number of users present at home in each time step is used to define the internal gains due the occupancy. The second effect of the occupancy is related to the use of appliances. When the users are active at home, they have assigned randomly an activity, also based on information from [11]. Each activity has related an electric consumption (television, PC, washing machine…). In a

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similar way the DHW is obtained; depending on the activity, different hot water profiles are applied.

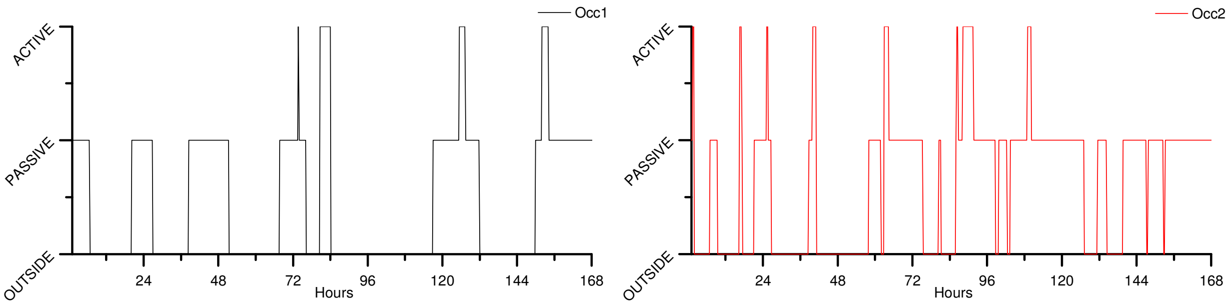

Figure 3 Example of the occupancy profile for a household with 2 occupants during 1 week. On the Y-axis is the state of each occupant every 15-minute (outside of home, passive at home and active at home).

The natural ventilation is also related to the occupancy, however it is not the only factor that takes part. The natural ventilation depends on the operative temperature and the occupancy. The strategy defined for the natural ventilation is based on the following assumption: the users use the natural ventilation for keeping cool the household, if the natural ventilation is not enough and the operative temperature is outside the comfort range, then, the windows are closed and the cooling system is switched on. Finally, the renovation rates are chosen depending on the building configuration: 1-side ventilation, cross ventilation and stack effect.

The use of external solar protections, as for example sunshades and blinds, is considered only in warm season and their use depends on the occupancy and the total incident radiation on the windows.

The artificial lighting is controlled by occupancy and daylighting. To switch on the lights are needed active occupants and not enough available daylight. The conversion of radiation to irradiance is based on the simplified method proposed in French building regulation [12].

Energy systems

A simplified method is used for the heating and cooling demand calculation. The demand is obtained as an ideal system with a limited power to cover the load. The heating and cooling demand are calculated using an appropriate set point temperature to have comfort conditions. The thermal losses due to the emission heating system are calculated according to the standard EN 15316-2-1 [13]. The energy consumption is obtained considering the energy performance of the corresponding system (natural gas boiler, heat pump, biomass boiler…).

Primary energy balance

With the integration of on-site renewable energy generation a balance between weighted demand and weighted supply (i.e., import/export balance) needs to be performed to compute the final primary energy consumption (1), as it is generally described in [14].

$$\mathrm{EP} = \int_{\mathrm{year}} [\mathrm{e}_{\mathrm{i}}(\mathrm{t}) \cdot \mathrm{w}_{\mathrm{g,i}}(t)]dt - \int_{\mathrm{year}} [\mathrm{d}_{\mathrm{i}}(\mathrm{t}) \cdot \mathrm{w}_{\mathrm{l,i}}(t)]dt \quad (1)$$

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where e and d stands for exported and delivered (i.e., imported), respectively; w stands for weighting factor to convert to primary energy and i for energy carrier (electricity, natural gas, oil, biomass, etc.).

Comfort evaluation

A comfort evaluation has been integrated in the simulation process, based on the Fanger model [15] and the ASHRAE adaptive model [16]. The Fanger model is applied in buildings with heating and cooling systems; and in contrast, the ASHRAE adaptive model is applied in buildings without mechanical cooling.

The comfort evaluation can be done at the time step level or a defined period, using short-term index or long-term index. The selection of the comfort index is based on Carlucci [17], which makes a detailed analysis of the different index and their applicability. The short-term index used are PPD (Predicted Percentage of Dissatisfied) and ALD (ASHRAE Likelihood of Dissatisfied), for each comfort model (Fanger and Adaptive). Using these indexes, it is possible to carry out the long-term evaluation, calculating the Long-term Percentage of Dissatisfied (LPD) (2).

$$LDP = \frac{\sum_{t=1}^{T}\sum_{z=1}^{Z}(p_{z,t} \cdot LD_{z,t} \cdot h_t)}{\sum_{t=1}^{T}\sum_{z=1}^{Z}(p_{z,t} \cdot h_t)} \qquad (2)$$

Where LD is the Likelihood of Dissatisfied (PPD or ALD); p is the ratio of occupancy (number of occupants divided per number of possible occupants); t is the time step; T is the period of calculation; z is the number of zones considered in the building or household.

Obtaining the LPD, it is possible to evaluate the discomfort due to overheating and/or overcooling, overall the year or only for determined period. Then it is possible to detect the weakness of the building and try to apply the proper measure in each case.

Energy efficiency measures

Three strategies for reducing energy consumption are considered: reduce the energy demand, improve the efficiency of the systems and introduce renewable energies.

Passive measures are analyzed to reduce energy demand, including façade insulation, roof insulation, improve the windows performance and the use of solar protections. In addition, measures focused on the improvement of the tightness of the construction are also considered. Most of the measures have an impact on the reduction of the coldbridges, which effect has also been estimated.

The active measures have the objective to reduce the primary energy consumption thought: the improvement of the performance of the heating and cooling systems, lighting and appliances; applying strategies of management and using renewable energy systems.

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Global cost evaluation

The economic evaluation of the study is based on the method established by the EPBD and described in the EN 15459 [18]. The method is implemented in TRNSYS, as Villa described in [19].

The economic analysis proposed by the EPBD evaluates the costs for an energy efficiency project during a period. The evaluation is based on global costs calculation, which includes: annual energy costs, the investment and replacement costs of the energy efficiency measures and the operational costs of the building and their systems.

Optimization and cost-effective evaluation

The multicriteria optimization is carried out with ZEUS. ZEUS is a simulation model that makes possible to find optimal values for several building parameters and the associated impacts that reduce the energy demand or consumption of the building. The simulation tools used are SDLPS (to rule the main simulation process) and TRNSYS (as a calculus engine for energy simulation) [5]. The optimization process is divided in two steps:

- Passive optimization: the objective of this first optimization is to reduce as much as possible the thermal discomfort with the minimum investment and operational costs. These simulations are run in a free-running mode, and the aim is to achieve thermal comfort in the building without the use of heating and cooling systems. In that case, the comfort model used is the ASHRAE adaptive model.
- Active optimization: for the buildings where the comfort is not guarantee only with passive measures, the best passive measures are combined with the active ones (energy systems). In that case, the objective of the optimization is to minimize the primary energy use and the global costs, obtaining the cost-effective measure. Now, the simulations are run with heating and cooling systems and therefore the thermal comfort requirement will be reached.

Conclusions

The method proposed in this paper aims to have a complete process for developing cost-effective studies of energy efficiency measures for building renovation. The method takes into consideration a detailed user behavior, building features updated with survey information, and thermal comfort criteria for the building design. The method integrates the process in two simulation tools: TRNSYS for the building, comfort and economic simulation; and ZEUS for the multicriteria optimization.

The method is a complex process that introduces: *innovative approaches*, as the two-step optimization considering comfort, energy and economic criteria; *realistic characterization*, with the use of stochastic profiles for the user behavior and its interaction with the building using Time Use Data, and the building parameters related to measurement and survey campaigns; the *economic evaluation* and the *cost-effective analysis* are done as defined by the European regulation; to prioritize the passive measures rather than the active ones, guaranteeing the *thermal comfort of the users*.

Acknowledgements
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References

[1] European Commission (2010). *Energy Performance of Building Directive (EPBD). 2010/31/EU*.
[2] European Commission (2012). *Energy Efficiency Directive. 2012/27/EU*.
[3] Ortiz, J., J. Salom, E. Cubí (2012). *Potential Impact Evaluation of the MEDBEES First Draft. MARIE project*, Programme Med.
[4] SEL (2012). TRNSYS 17.1, Madison: Solar Energy Laboratory. University of Wisconsin.
[5] Fonseca i Casas, P., A. Fonseca i Casas, N. Garrido-Soriano, J. Casanovas (2014). Formal simulation model to optimize building sustainability. *Advances in Engineering Software*, 69(0):62-74,
[6] Estudi Ramon Folch (ERF) (2014). *Caracterització del parc existent d'edificis d'habitatges de Catalunya*, Barcelona.
[7] Manyes, A., L. Sisó, J. Salom (2013). Block level study and simulation for residential retrofitting. *BS2013: 13th Conference of the International Building Performance Simulation Association*, Chambery, France.
[8] UNE (2007). *UNE-EN 15242: Ventilation for buildings. calculation methods for the determiantion of air flow rates in buildings including infiltration*.
[9] Alfano, F.R.d.A., M. Dell'Isola, G. Ficco, F. Tassini (2012). Experimental analysis of air tightness in Mediterranean buildings using the fan pressurization method. *Building and Environment*, 53(0):16-25,
[10] Jimenez Tiberio, A., P. Branchi (2013).A study of air leakage in residential buildings, in: New Concepts in Smart Cities: Fostering Public and Private Alliances (SmartMILE), pp. 1-4.
[11] Instituto Nacional de Esatdística - España. Encuestas de Empleo del Tiempo 2009-2010
[12] Centre Scientifique et Technique du Bâtiment (CSTB) (2012). *Méthode de calcul Th-BCE 2012*.
[13] UNE (2008). *EN 15316-2-1: Heating systems in buildings. Method for calculation of system energy requirements and system efficiencies. Space heating emission systems*.
[14] Sartori, I., A. Napolitano, K. Voss (2012). Net zero energy buildings: A consistent definition framework. *Energy and Buildings*, 48(0):220-232,
[15] UNE (2006). *ISO 7730: Ergonomics of the thermal environment - Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria*.
[16] ASHRAE 55 (2004). *ANSI/ASHRAE Standard 55-2004, Thermal environmental conditions for human occupancy*, Atlanta, American Society of Heating Refrigerating and Air-Conditioning Engineers Inc.
[17] Carlucci, S. (2013). *Thermal comfort assessment of buildings*, Spinger.
[18] CEN (2008). *EN 15459: Energy performance of buildings - Economic evaluation procedure for energy systems in buildings*.
[19] Villa, M. (2013).Herramienta de evaluación económica de proyectos energéticos integrada a TRNSYS, UPC.

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Urban energy interventions in Oostland, Netherlands: bottom-up towards sustainability

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Abstract: *The provision of sustainable energy requires more spatial impact than a system on conventional energy. This makes the energy transition largely a local assignment. Local governments are however, struggling to find ways to intervene in their districts. Developing more cellular urban energy plans, that cater for a bottom-up approach involving other local actors, may therefore provide a more successful path to a fully renewable system.*

The method of Energy Potential Mapping (EPM) serves to define, allocate and quantify local energy demand and sustainable potentials or even extended on exergetic (quality) and temporal values. Several local limitations, of technical, political and financial nature are taken into account. With this layering of 'maps' a local energy catalogue is created that may serve as a basis document to design, discover and dimension local sustainable interventions in the built environment. This energy potential catalogue, combined with an energy strategy or approach, helps local governments or other stake holders to get a step closer to define applicable interventions and realize them. An example of such a strategy is the Rotterdam Energy Approach and Planning (REAP) method, which involves applying the New Stepped Strategy of reducing, reusing and generating sustainably in a spatial manner, and connecting different urban scales from buildings and neighbourhoods to cities and regions.

In this paper the EPM method will first be discussed and moreover some common strategies towards sustainable interventions. The focus however, will be on the application of these methods and strategies in the case study (2013) of the Dutch region of the Oostland, in which both municipalities and local entrepreneurs were involved. This study was implemented in the West of the Netherlands, in an urban-rural greenhouse area of around 100 km^2. The specific aim was to propose local short-term energy-based plans; formulating these is a typical present-day challenge faced by European local governments. By examining the results of this study, the energetic analysis of the area will be described incrementally, culminating with the best achievable interventions. Using several examples of smartly connecting demand and supply, cascading energy streams and exchanging local heat and cold, the approach here will be explained.

Keywords: urban energy systems, sustainable intervention, sustainable development, energy potential mapping, built environment, heat network, heat cascading, heat exchange, horticulture, greenhouse, geothermal heat

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Energy Potential Mapping method (analysis)
The Energy Potential Mapping (EPM) method was initially developed to visualize local (renewable) energy potentials and demand of energy, in order to support spatial planning towards more energy-efficient urban or rural environments (Dobbelsteen, et al., 2011). EPM has evolved over the years and led to a process whereby energy becomes an extra parameter of spatial planning during the design of sustainable built environments.

Until now, fossil fuels (with a high energy density, being extracted from the underground, easy to transport and converted at central locations into for example electricity) have been sufficiently available, so historically the distribution of energy has hardly interfered with spatial planning. In a future energy system, however, renewable sources will mostly need to be accessed at or near the Earth's surface, have a low energy density, are spread out over larger areas, with its supply not always simultaneously with the demand and some forms tend to be less easy to transport.

This means that in a sustainable world based on renewables, **energy = space**, and sources and sinks must be spatially connected in smart ways. The EPM method is a means to map and quantify renewable energy potentials (e.g. solar, wind, geothermal, and biomass) and demand in an easily comprehensible way (Broersma, et al., 2013).

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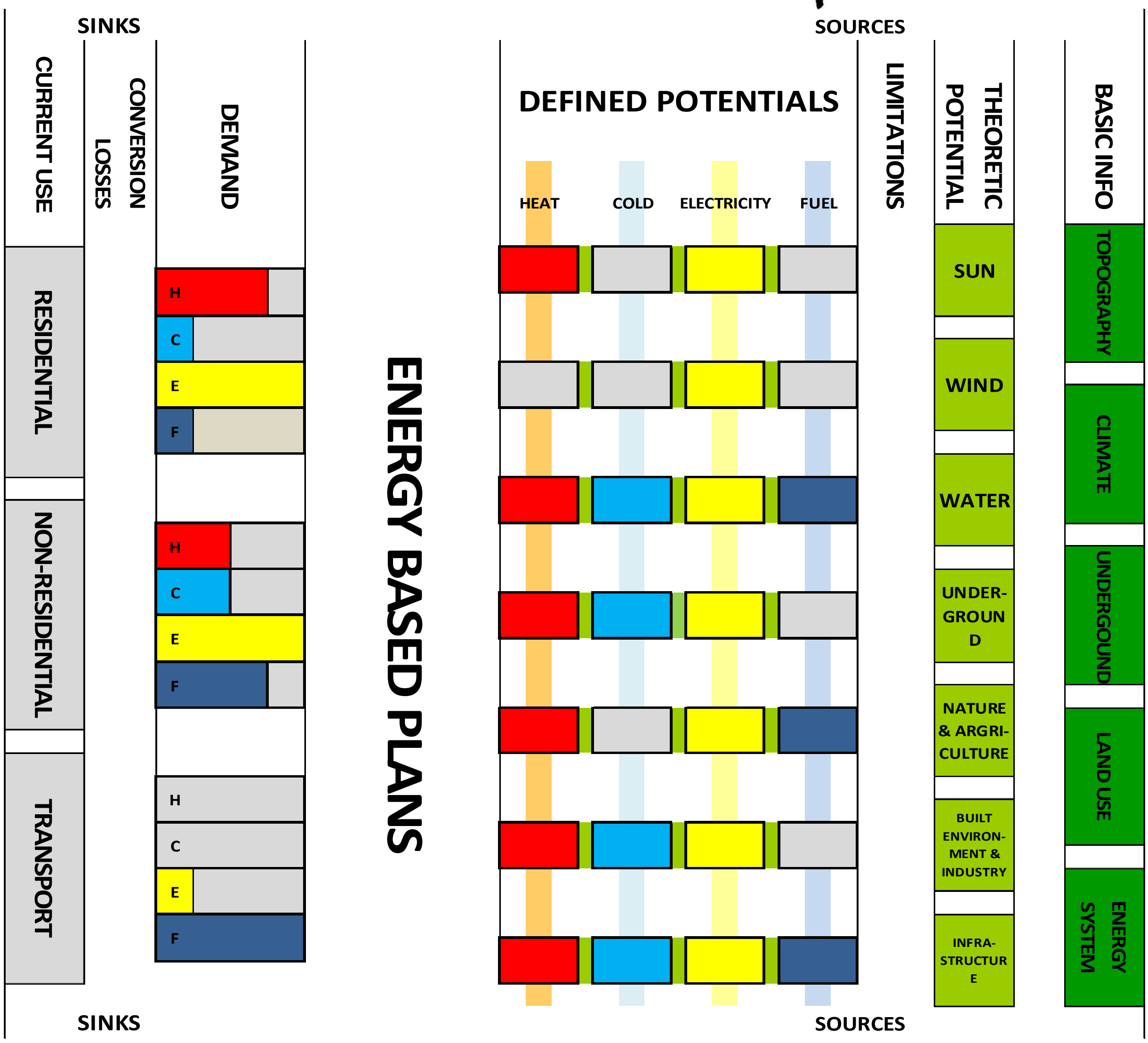

Figure 4: method of Energy Potential Mapping

Figure 4 illustrates the method of EPM, starting on the left with redefining the current primary energy use in an area (for example a region, city or neighbourhood) into the actual energy demand of heat, cold, electricity and fuel. Simultaneously on the right, the theoretic potentials are defined out of the basic input for each source and into the available heat, cold, electricity and fuel after regarding the limitations. Sources and sinks meet in the middle, where they can be smartly connected in energy based plans. To define these plans other methods can be applied.

All sources of energy may be subject to an EPM study, but most often renewable and anthropogenic (e.g. residual heat) sources are studied. The demand comes mainly from buildings or transport and can be subdivided again into different functions e.g. dwellings, commercial and industrial buildings, greenhouse districts; Next, the functions' demand can be divided into the types (heat, cold, electricity, liquid or solid fuel). The potentials are subdivided to their source and into types again. The goal and desired output of the study have to be determined in advance and checked with the availability of data and if necessary adjusted to the latter.

EPM can serve as a basis method to provide an area with its energetic characteristics when a city or region wants to improve its ecological footprint. But to discover what its best achievable and most suitable sustainable interventions are, an additional approach, strategy or method needs to be applied.

Methods and strategies towards interventions

At the basis of our urban energy approaches is the New Stepped Strategy (NSS), summarized as **reduce, reuse and generate sustainably**, and displayed as a series of spatial flows in Figure 5. Most present day energy systems (represented here by the grey arrows) both generate exactly the amount of energy required (still primarily using fossil fuels) and discharge waste outside the region (for example as CO_2 into the global atmosphere). Not only does this involve a finite energy source frequently imported from abroad, the lengthy transport and distribution system introduces additional vulnerabilities, both technical and geopolitical.

Energy systems therefore benefit from mainly using local and regional sources, which are frequently of a renewable nature, and only any demand still remaining has to be imported, or the surplus can be exported. As renewable sources tend to have a fluctuating output, a fully renewable system for a specified area will most likely both include a mix of sources as well as a means of energy storage (for example biomass or seasonal thermal energy storage), and reduce peak demand by shifting loads (for example running washing machines on sunny or windy days).

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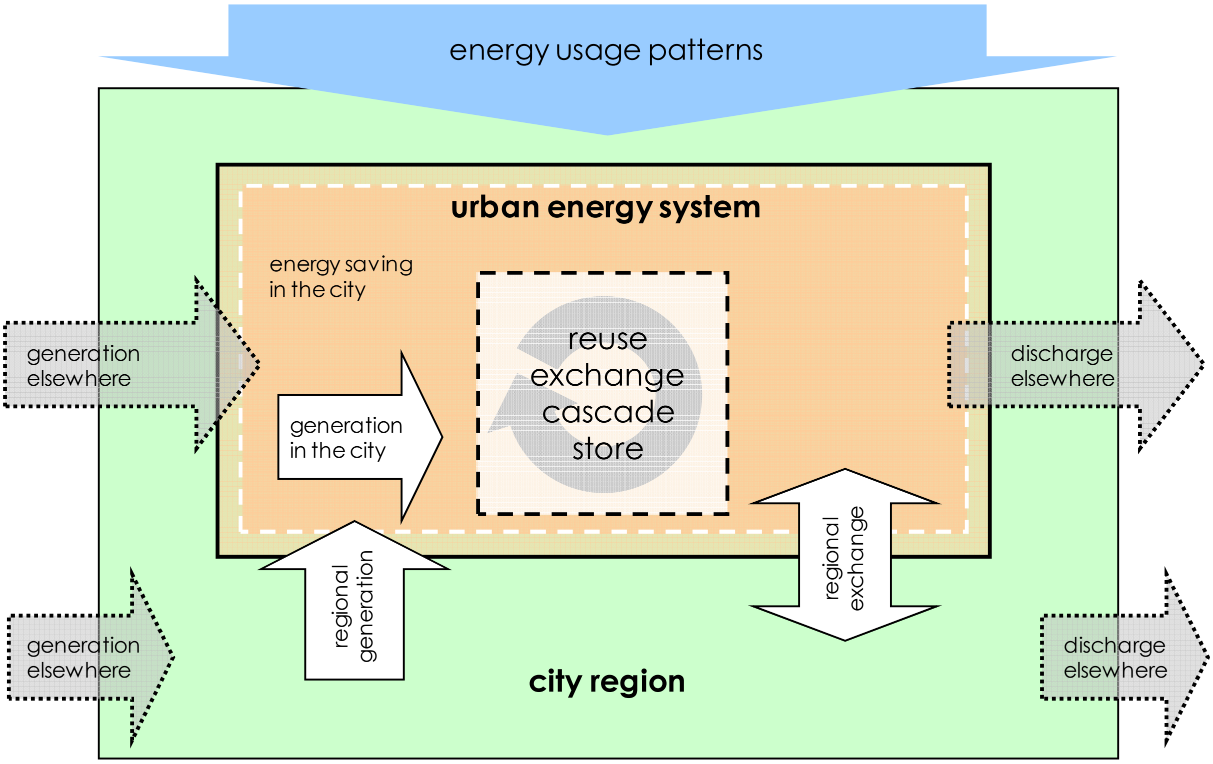

Figure 5: urban and regional energy flows

The **Rotterdam Energy Approach and Planning (REAP)** method (Tillie, et al., 2009) applies the NSS with the goal of closing energy cycles in the built environment at various scales ranging from individual buildings to entire regions. The basic premise (Figure 6) is that buildings are not individual, closed systems, and measures taken on one scale will affect others, the interconnectivity between scales therefore improving the efficiency and robustness of the urban energy system as a whole. Examples at increasing scales are reducing heat demand by insulating individual buildings, a neighbourhood district heating network using a geothermal well and a coastal wind turbine park providing a region with electricity.

The **Amsterdam Guide to Energetic Urban Planning** (or **Leidraad Energetische Stedenbouw**, **LES**) (Dobbelsteen, et al., 2011) provides a practice oriented handbook that combines EPM and REAP, with which both new and existing neighbourhoods can be made climate neutral, and includes fact sheets with practical measures ranging from solar orientation for new developments to bio-CHP applications. Plans and variants using these measures can be tested using spreadsheet calculations, in order to gauge combined effectiveness.

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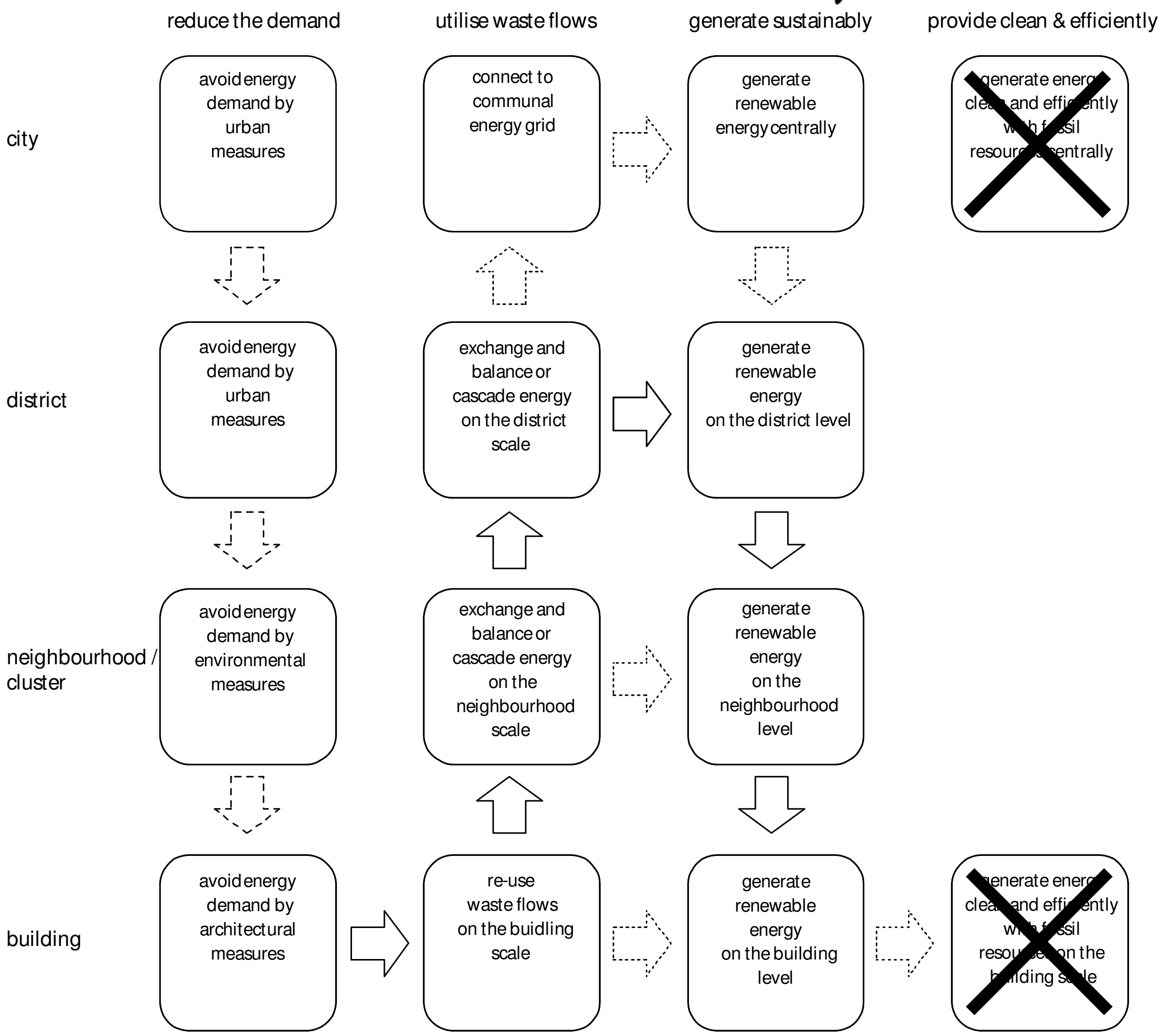

Figure 6: REAP method – applying the NSS steps (x axis) to different scales (y axis)

Oostland approach: short-term interventions towards full sustainability

Although an ever increasing number of local governments aims to improve sustainability of their areas, in the post financial crisis world financial resources tend to be limited. They can however facilitate initiatives and for example adapt local regulations, and there are also many progressive citizens and entrepreneurs with funds, properties, knowledge of subsidies and regulations and enterprising spirits, providing fertile ground for a bottom-up approach. The latter groups however tend to lack the knowledge required to determine which measures should be applied where, taking into account an urban area as a whole. The Oostland approach brings together all these stakeholders into a consortium and provides them with the information (both energy potentials and viable combinations of measures) they need, in order to formulate short term interventions appropriate to the local situation and suitable for later integration, the so-called palette of possibilities.

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As implied by the name, the approach was developed in a recent study (Broersma, et al., 2013) of the Oostland region (east of The Hague, in the Netherlands). This area consists of the Pijnacker-Nootdorp and Lansingerland municipalities and is dominated by horticulture between the towns of Bleiswijk, Bergschenhoek and Pijnacker. Conventional greenhouses tend to be significant energy users, but have great potential not just in simply reducing their demand but also in downright generation, as well as cascading and exchanging with surrounding areas.

The Oostland study was executed at the request of a group of progressive sustainable entrepreneurs from the region. The specific goal of this research was to discover interventions that would lower the region's energetic footprint, could be implemented on the (relative) short term and would fit in an overall vision for the region.

In order to reach this goal, the first part of this study involved mapping the region's energy potentials using the EPM method. The second part consisted of defining several principles of sustainable interventions, and finding suitable locations in the region for each of these; where they could be implemented and operated independently initially, but fit in an overarching scenario towards a robust, interconnected and fully sustainable system. During the final workshops the group of entrepreneurs was extended with representatives from both municipalities and several specialists, in order to discover the best business cases out of the proposed interventions.

EPM Oostland: regional demand and sustainable potentials

During research, the first step resulted in a series of energy potential maps, some of which are shown in Figure 7. Topics include electricity and heat demand of dwellings, greenhouses and other non-residential functions; electricity and heat generation potential from surfaces that would allow energy generation as a secondary function (mainly south facing roofs; use of primary surfaces is excluded as that would interfere with other functions); ground source heat pump (GSHP) potential; intermediate and deep geothermal potential for suitable aquifers, and finally potentials for biomass and wind. Being in the vicinity of an airfield (Rotterdam Airport) meant that for the latter potential, turbine height restrictions had to be taken into account, requiring wind turbine plans to be focused on the northern half of the region.

For biomass, only waste flows were investigated. For electricity and heat generation, only surfaces were considered that would get a second use with energy generation (roofs, roads etc. First generation biomass is renewable, yet not considered sustainable and not taken into account here.

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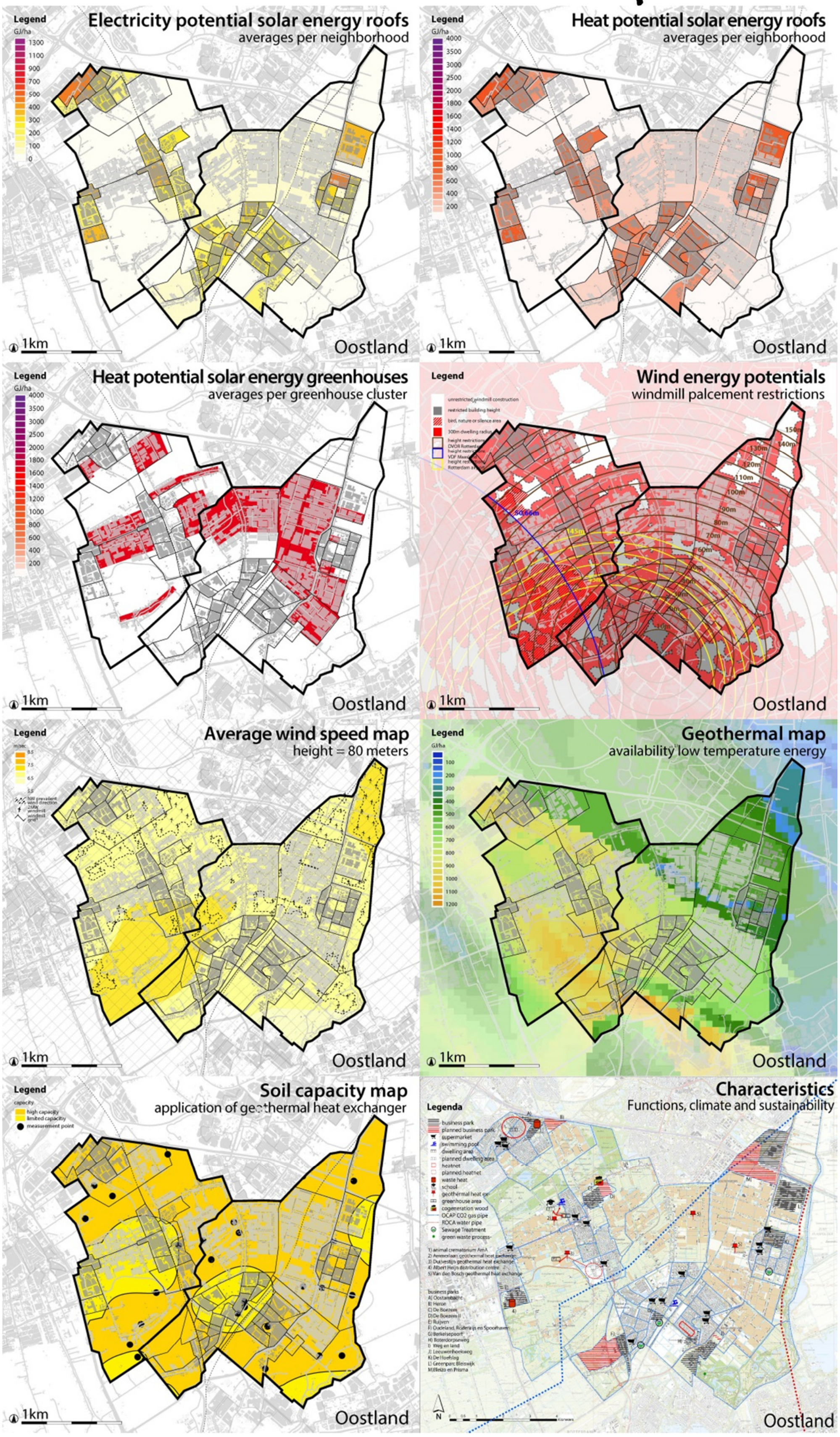

Figure 7: Energy Potential Maps: demand and supply

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Examples of short-term interventions

The combined results provide an energy catalogue for the region, which was used as a basis for defining local short term interventions; first as generic concepts suitable to the now known Oostland energy mix, and subsequently as specific proposals connecting and quantifying the best fitting local sources and sinks.

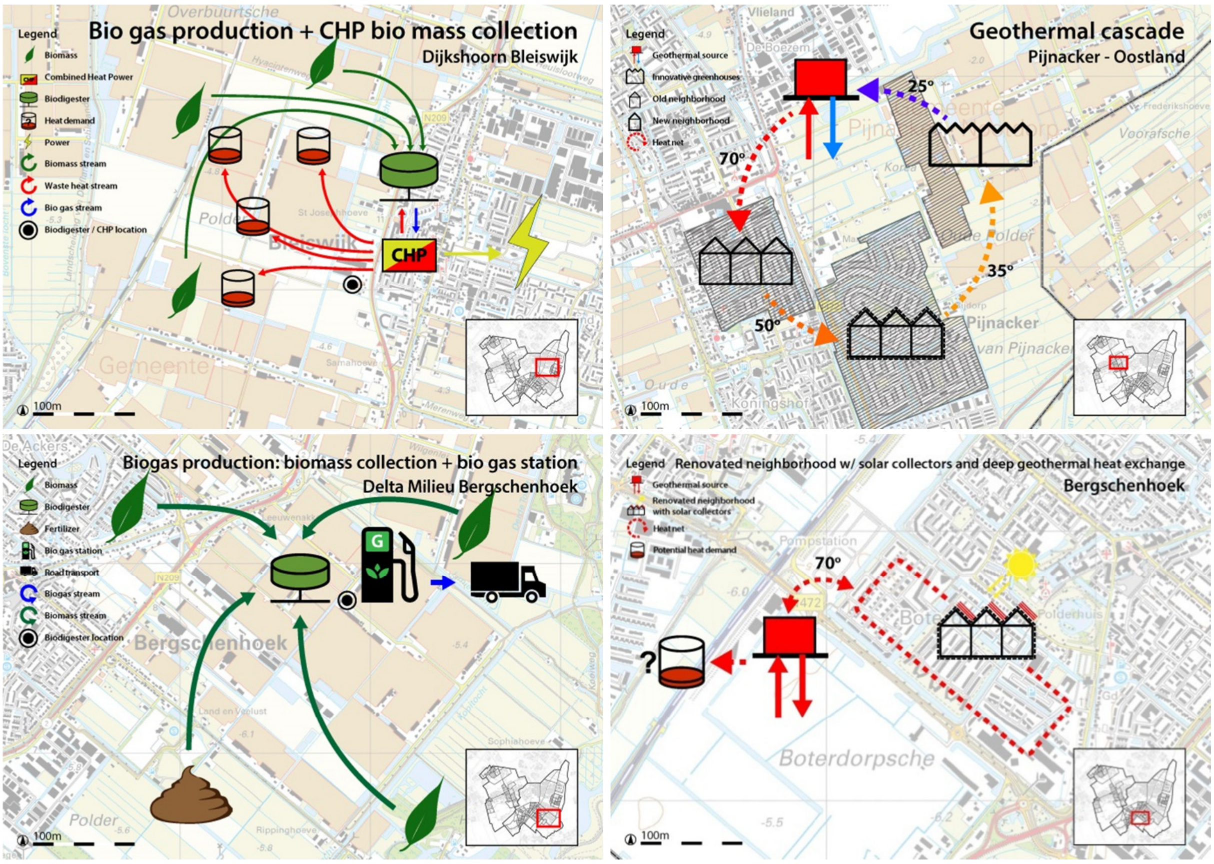

Figure 8: schematic examples of local sustainable interventions projected on the map

Figure 8 shows a few examples of these proposals, the concepts having been projected on specific map locations. In the town of Bleiswijk (top left), a biogas production plant and combined heat and power station (CHP) were proposed at a biodegradable waste collection point located in a greenhouse area. This would allow the closing of several cycles, as the biodegradable waste from the greenhouses is fed into an anaerobic digester, producing biogas for the CHP plant, where it is converted into electricity and CO_2 for the greenhouses. Finally, the residual digestate from the biogas phase can be returned to the greenhouses as a soil conditioner.

The geothermal cascade proposal (top right) is based on the idea of extracting a significantly larger amount of thermal energy out of a single well, by reducing water temperature as much as possible before reinsertion in consecutive usage steps, a concept known as cascading. This requires the vicinity of sinks with a comparable energy demand but at different temperature ranges. The ground below the town of Pijnacker is quite suitable for geothermal heat extraction. Furthermore, part of the old town centre requires a heating inlet temperature of (on average) 70°C and has an outlet temperature of 50°C, which means this can subsequently be fed into a more recently built, better insulated neighbourhood and, after that, be used in the newly planned adjacent greenhouse area. This would result in a final outlet temperature for the cascade of about 25°C, therefore making much better exergetic use of the same amount of heat. (The 3rd and 4th example are not further explained here.)

Long-term vision: a naturally expanding district heat network

For Pijnacker (a town in Oostland surrounded by many greenhouses) a long-term vision towards self-sufficiency (for heat) has been proposed and the pathway towards this vision. The principles behind this pathway and vision will be described next.

Two geothermal heat wells are already in operation at horticultural companies in Pijnacker, which not only provide for greenhouses but also an adjacent secondary school, a sports venue, several neighbouring greenhouses and soon a residential area which is currently under development.

There are many more different options to generate heat locally, especially in combination with horticulture. The underground in the area is very suitable for more use of geothermal energy. Greenhouses also receive much more heat from the sun than they need throughout the year and the soil is well suited for heat storage. The use of the concept of the closed greenhouse (InnovatieNetwerk, 2014) can therefore provide a large amount of low temperature heat. A closed greenhouse extracts excess summer heat through heat exchangers and stores this in the underground.

The municipality could invest in the construction of a heat network for existing dwellings and other buildings in Pijnacker, but struggles with the question of how the development of renewable heat systems in horticulture will be. Will ‘closed greenhouses’ with their large supply of low-grade heat, for example, be common in the future? Or, on the other hand, should the municipality focus on saving energy by energy renovation of the existing building stock in which local heat pumps will provide heat?

The proposed long-term vision, however, is based on the local production of heat, transported through a smart district heat network that can grow naturally. The starting point for this is that there are many technical possibilities for the production of (low temperature) heat in the area and demand for heat is nearby.

In Figure 9, examples of these sustainable heat systems are schematically shown (sources indicated with a **+** and sinks indicated by a **-**) and at what temperatures they may operate. Often a heat pump will be needed, in case of soil storage, to increase the temperature.

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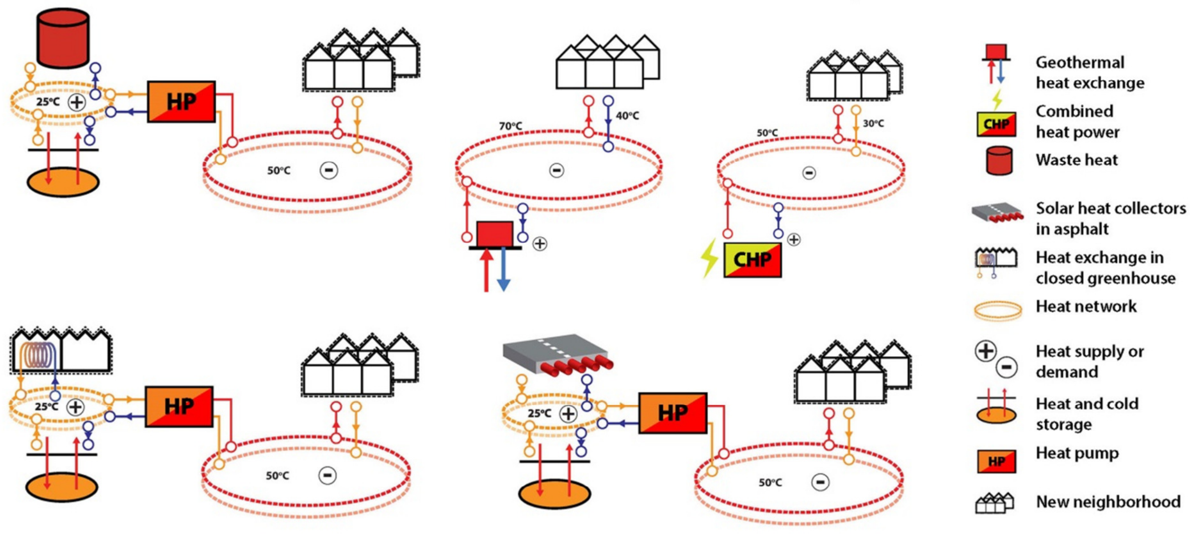

Figure 9: diagrams of sustainable heat systems

When a certain 'critical mass' of various implemented heat projects has been reached it will be beneficial to interconnect the individual district heat networks. This makes it possible to use multiple sources, resulting in a more robust network and allowing more distant sources and sinks to be connected to each other.

A combined network however requires a single temperature, whereas previously the smaller systems could operate at different temperatures. In that case heat pumps can upgrade the temperature of the main network, if higher temperatures are (temporarily) required, for example for an older residential area that hasn't been refurbished yet.

When designing the connecting network, future heat systems that only require low temperature heat can be anticipated by dimensioning for lower temperatures (requiring a larger pipe diameter). This would facilitate a future situation, with for example an increasing number of 'closed greenhouses', as this makes it possible to decrease network temperature, so the total system will work at its optimum. If, on the other hand, more geothermal heat will be used, the network temperature will be higher. The ability to cater for both options within the overall network therefore facilitates a wide range of possibilities for bottom-up 'natural growth'.

The final vision of a large connected heating system for Pijnacker is depicted at the top of Figure 10. The smaller pictures below represent the steps of the pathway towards this vision.

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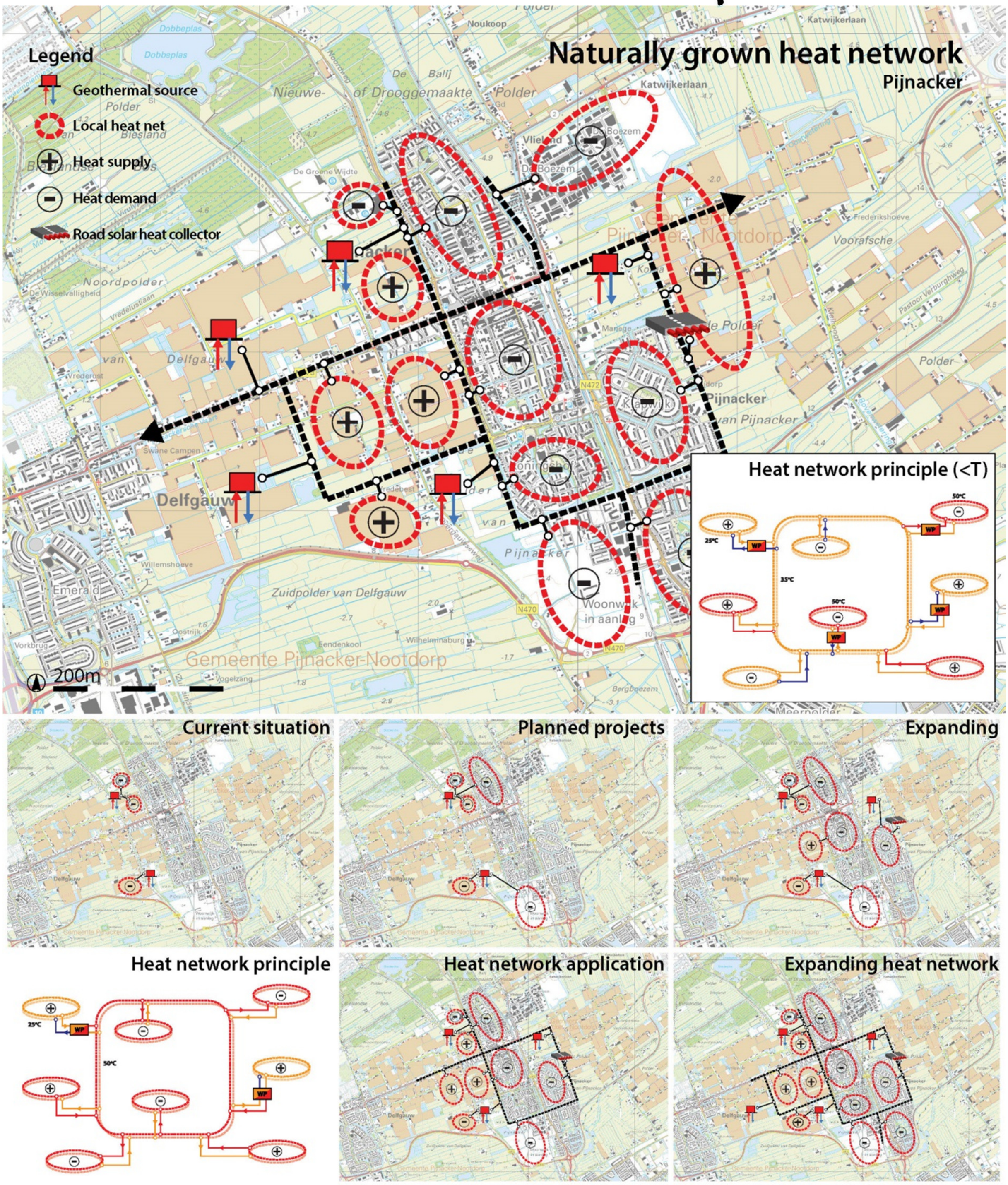

Figure 10: concept for a growing district heating infrastructure for a self-sufficient Pijnacker

Conclusions

Sustainability can be boosted structurally by municipalities or other local authorities without requiring immediate grand investments. A thorough investigation of the region's energy characteristics, combined with a palette of self-contained but interconnectable local sustainable interventions can provide a wealth of options towards a fully sustainable plan, which a consortium of local sustainable-minded entrepreneurs, local officials and specialists can use to further exploit the proposals and formulate individual business cases.

Apart from smaller scale self contained interventions for the Oostland region, a long-term vision for the municipality of Pijnacker was defined. This vision is not intended to provide a detailed blueprint for a complete renewable energy system, but shows how in several steps a self-sufficient district heating system can be developed in which a certain level of future uncertainties is taken into account. Although the Oostland case describes a solution for an area with many greenhouses, the underlying principles can be applied to other built environments as well.

Regions like Oostland with large horticultural areas close to the built environment and provide abundant opportunities for intelligently connecting sources and sinks through a naturally growing heat network. Conversely, new horticulture should be developed near existing built up areas in order to integrate their energy systems and provide increased synergy.

There are many approaches, strategies and methods that can contribute at different levels to discovering visions, scenarios, master plans and single sustainable interventions in a region or city and implementing them successfully. The example of Oostland showed the combination of energy potential mapping for the energetic analysis and for defining interventions and an approach of getting local ‘early adaptors’ who want to integrate sustainability into their region, into a consortium. Yet continued research into sustainable approaches and methods can improve on this by structurally including more local limitations of technical, governmental, economical, process and other natures, increasing the chances of successful future integration and long term sustainability even more.

Sources

Broersma, S., Fremouw, M. & Dobbelsteen, A. v. d., 2013. *Energiepotentiestudie Oostland - Met een regionale energie-analyse naar lokale duurzame ingrepen,* Delft: Delft University of Technology.

Broersma, S., Fremouw, M. & Dobbelsteen, A. v. d., 2013. Energy Potential Mapping: Visualising energy characteristics for the exergetic optimisation of the built environment. *Entropy,* Issue 15, pp. 490-506.

Dobbelsteen, A. v. d., Broersma, S. & Stremke, S., 2011. Energy Potential Mapping for energy-producing neighborhoods. *International Journal of Sustainable Building Technology and Urban Development,* 2(2), pp. 170-176.

Dobbelsteen, A. v. d. et al., 2011. *The Amsterdam Guide to Energetic Urban Planning.* Amsterdam, Management and Innovation for a Sustainable Built Environment conference.

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InnovatieNetwerk, 2014. *Kas als energiebron in de Zonneterp.* [Online] Available at: http://www.zonneterp.nl/energieproducerendekas.html

Tillie, N. et al., 2009. Towards CO2 neutral urban planning: Presenting the Rotterdam Energy Approach and Planning (REAP). *Journal of Green Building,* 4(3), pp. 103-112.

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Regionalization of building-stock description as basis for evaluating energy conservation measures –South East Norway and South West Sweden

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Abstract: *This paper presents a description of regional building stocks in the South West of Sweden and the South East of Norway and provides a first validation by means of modelled Final Energy Demand, which is compared with available statistics. The aim of the work is to provide a basis for modelling the assessment of effects and costs of various energy conservation measures applied to the existing building stocks of regions within a country. The aggregated descriptions of the national building stocks of Sweden and Norway through representative buildings are downscaled to the regions. We conclude that the uncertainty in the methodology applied is higher for the regions than for the national level, due primarily to less data available for validation than on the national level. This uncertainty raises concern about how targets on increased energy efficiency and emissions reductions and are going to be monitored, if such targets are to be fulfilled.*

Existing building stock, interregional, sustainable energy system, energy carrier, KASK-region

Introduction

The present work is motivated by the fact that, in spite of that most municipalities of the two regions studied have targets and visions on reductions in energy use and greenhouse gas (GHG) emissions, there is a lack of clear descriptions (pathways) of how to reach these targets and visions. In the building sector there is a large potential for reductions in energy use since buildings typically use some 40% of the energy in European countries. However, there is a need for a detailed description of the characteristics of the building stock to which energy modelling can be applied in order to assess the cost and potential contribution of different energy conservation measures (ECMs). Knowledge regarding the characteristics of building stocks is key to understanding how the energy performance of the building stock can be improved. However, most studies on the energy performance of building stocks are strongly limited by the absence of reliable statistical data. In a series of previous works we have developed a methodology to assess the potential and cost of ECMs applied to national building stocks, including both a description of the building stock of key EU member states (1) and a modelling methodology for assessment of ECMs (2). The present paper aims at performing the same analysis for a region *within* a country in order to investigate the applicability of the methodology to a region with limited geographical scope. The analysis is carried out for two regions comprising the South West of Sweden and the South East of Norway.

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The KASK regions and their energy system

The two regions investigated belong to the so called Kattegat-Skagerrak (KASK) region. Together the two regions consist of 175 municipalities with a total area of 72,400 square kilometres and a population of 3.8 million. The Swedish KASK region is divided into two counties; Västra Götaland county (VG) and Halland county with 49 and 6 municipalities, respectively, and 17% of the population in Sweden. Combined the two regions emitted 22% of total GHG emissions in Sweden

The Norwegian KASK region constitutes 8 counties and 124 municipalities, and 45 % of the total Norwegian population.24 % of Norway's GHG emissions Due to the large scatter in population density, industry structure, topography and societal characteristics within the Norwegian KASK region we have aggregated the data into urban and rural areas. These are hereafter referred to as Urban KASK-NO (including the counties of Oslo and Akershus) and Rural KASK-NO (including the counties of Østfold, Vestfold, Buskerud, Telemark, Aust-Agder and Vest-Agder). Table 1 provides basic characteristics of the two regions investigated with regard to size, energy consumption and GHG emissions.

Table 1: Characteristics of the KASK Region.

	VG	Halland	Total KASK-SE	Urban KASK-NO	Rural KASK-NO	Total KASK-NO
Population (end 2012)	1 612	306	1 918	1 124	1 207	2 331
Approximate area [km²]	23 942	5 454	29 396	5372	53048	58420
Population density [/km²] - 2012	67	56	65	209	23	40
Number of municipalities	49	6	55	23	101	124
Primary energy supply [TWh/year][1]	69.6	63.1	133	24.9	66.4	91.3
Final Energy Consumption (FEC) [TWh/year][2]	66.1	13.9	80.0	24.3	46.2	70.5
FEC in the housing sector [TWh/year][2]	9.7	2.5	12.2	9.5	12.1	21.6
GHG emissions/capita, tCO_2e[2]	7.7	6.2	7.5	2.9	7.6	5.3

[1] Swedish data from 2008, Norwegian data from 2009
[2] Swedish data from 2010, Norwegian data from 2009

In the **Swedish KASK** the electricity is generated mainly by hydro, nuclear and biomass, the latter mostly in combined heat and power plants. In addition, district heating, is mostly produced from biomass and waste combustion (59%), heat pumps (12%), and waste heat (11%). SFDs are mostly heated by electricity or biomass, while over 90% of MFDs use district heating (3). District heating is also the dominating heating carrier (over 70%) for non-residential buildings. In the **Norwegian KASK** the energy system is characterized by large amount of hydro power. In 2009, hydro power accounted for 95.7 % of the total power generation whereas wind power accounted for 0.7 % and thermal power for 3.6 % (4). Electricity is the dominating energy carrier in households in combination with biomass (firewood). The use of heat pumps has been increasing the later years. District heating is used to some extent in the urban part of the region, in particular Oslo, and is increasing.

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Methodology

This work combines the above mentioned methodologies previously developed by the authors for building-stock aggregation of national building stocks through archetype buildings (1), and assessment of ECMs by means of the ECCABS building-stock model (2). The results from the modelling are compared with available statistics with the aim to validate the building-stock description with a regional scope. Thus, when validated, the building-stock description and the modelling will form a basis for evaluating the effects and costs of different ECMs. The methodology for building-stock aggregation follows four steps: segmentation (in which the number of archetypes building is decided), characterization (in which the physical and technical properties of each archetype are described), quantification (in which so-called weighting coefficients are calculated, that represent the amount of buildings in the stock equal to each archetype) and validation of the final FEC in the building stock for a reference year.

Description of the building stock of the region

For the regions of this work, the methodology for building-stock aggregation through archetype buildings is applied as follows.

For **Swedish buildings**, a dataset for the national building stock was available from previous work. The dataset includes 1400 residential (R) *sample buildings*, which are different from the archetypes in that the samples correspond to actual buildings for which all input parameters have been obtained from measurements. The derivation of the Swedish national dataset and how it was used to study the entire Swedish residential stock is given in (5). The dataset also includes 384 non-residential (NR) archetypes buildings (6) which have been derived using the above referred methodology.

In the segmentation, the amount of sample R buildings in the national dataset (situated in 30 different locations) is downscaled by selecting only the buildings located in the Swedish KASK region: 181 single-family dwellings (SFDs) and 119 multifamily dwellings (MFDs) across 7 municipalities. Additionally, 2 new archetypes are defined to include, respectively, SFDs and MFDs built between 2005 and 2010 (the national dataset represents the Swedish building stock in year 2005). The NR dataset, which covers in total 14 building types, 8 different construction periods and 4 climate zones, have been downscaled by selecting only one of the climate zones, which results in 112 NR archetypes. In total, 414 archetypes are obtained to represent the Swedish KASK region. *In the characterization*, both for R and NR buildings the physical properties of the buildings and their energy use (for hot water, lighting and appliances) are assumed to be the same as in the national dataset due to lack of information on such building data on a regional level. The heating systems by fuel type are updated for SFDs based on data per number of dwellings from (7), for MFDs based on data for heated floor areas (8), and for NR buildings based on data for Western Sweden given in (9). In all the cases the fuel efficiencies are assumed to be the same as the national values given in (10). *In the quantification*, the weighting coefficients for R buildings are updated based on data from (11). The number of R buildings constructed after 2005 are taken from

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(12). For NR buildings, the updated weighing coefficients are calculated from the total number of buildings in each region (9), assuming that the share of the total area for a specific building category, within a construction period, is the same in the region as at national level, and that the average area of a premise (of a certain building type) is the same in region as the national average. The heated floor areas across the 8 construction periods in each region of Sweden, VG and Halland included, are found in (9)

For **Norwegian buildings** there was no national dataset available, thus the work started by developing an aggregated description of Norwegian R buildings by means of archetype buildings, following the methodology given in (1). *The segmentation* results in 126 archetype buildings, corresponding to 3 building types (SFDs; divided row houses; and MFDs), 6 periods of construction (before 1945; 1945-1970; 1971-1980; 1981-1990; 1991-2000; and 2001-2009), and 7 categories of renovation (13) (additional thermal insulation)(WFC; WF or WC; W; FC; F or C; New Windows; and unimproved, where W = walls and windows, F = floors, C = ceilings). In *the characterization*, the U values are determined based on different construction periods and information on energy renovations (13). Unknown surfaces of envelope (such as facades, cellars, roofs and windows) and building geometry are obtained according to the so-called 3CL-DPE Method (14). Assumptions on effective heat capacities of the buildings are taken from (15). Due to lack of data, ventilation rates, and heat gains from lighting and appliances are assumed to be equal to the corresponding values in the Swedish dataset. The type of heating system and their efficiencies are based on (13). In *the quantification*, the total number of buildings and their heated surface areas are extracted from (13) (16).

The dataset developed for Norway was downscaled to the region by means of a quantification which, similar to the Swedish case, simply assumes that the amount of archetypes and their characteristics are the same in the Norwegian KASK as for the entire country. The total number of buildings in the Norwegian KASK region was obtained by adding the number of buildings from each municipality of Norwegian KASK region (16). Input data for the buildings built during 2001-2009 were based on the building codes, effective from 2007 (13). Total heated floor area was obtained by multiplying the number of dwellings per construction period from (16) by average dwelling area per construction period from (13).

Results and Discussion

Tables 2 and 3 compare the modelled FEC for the Swedish and Norwegian KASK regions with corresponding data from statistics. For the Swedish KASK region the modelled FEC for SFDs and MFDs is 20% higher and 22% lower than statistics. This is a significantly higher deviation than the corresponding comparison made for the entire Sweden for which the modelled FEC for R buildings (only R buildings was studied) was only 3% lower than the corresponding value from statistics as shown previously (5). These deviations within the subtypes could be caused by deviations in the estimated distribution of heated floor areas within the representative buildings in the KASK region or by the fact that the buildings chosen within the Swedish KASK region are not representative of all buildings in the region

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(in spite of being representative of a particular segment of all Swedish buildings). We have so far not found any official statistics on heated floor area of the KASK region or any data on the building characteristics of the KASK region which show that the region differ from the country of Sweden with respect to building types.

For NR buildings of the Swedish KASK, the obtained FEC, number of buildings and heated floor area agrees rather well with the literature, i.e. with deviation from -6% (FEC) to 0% (Heated floor area).

Table 2. Comparison for the Swedish KASK region (in the reference year 2010) for annual FEC (TWh/yr), number of buildings(k) and heated floor areas (Mm^2), as obtained from the ECCABS modelling and the corresponding data available in statistics. The sources used for the comparison are specified in the table.

Subsector	FEC		No. dwellings/premises		Heated floor areas	
	This work	From statistics; *deviation*	This work	From statistics; *deviation*	This work	From statistics; *deviation*
R	*13.9*	*14.4; -3%* [1]	*744.4*	*744.4; 0%* (11) *747.7; 0%* [1]	*82.7*	*71; +14%*[1,2] *76.7; +7%* (17)[2] *75.8; +8%* (17)[3]
R-SFD	10.1	8.0*; +20%* (7)	333.8	333.8*; 0%* (11) 317.6*; +5%* (7) 327.9*; +2%* (17)[2] 324.9*; +3%* (17)[3]	46.6	40.2*; +14%* (7)[2] 48.3*; -4%* (17)[2] 48.1*; -3%* (17)[3]
R_MFD	3.9	4.7*; -22%* (8)	410.6	410.6*; 0%* (11) 425.3*; -4%* (8)	36.1	25.1*;+30%* (8) 30.8*; +15%* (8)[2] 28.4*; +21%* (17)[2] 27.7*; +23%* (17)[3]
NR	7.7	8.2*; -6%* (18)	14.0	14.4*; -3%* (9)[2] 14.7*; -5%* (17)[3]	23.0	23.0*; 0%* (9) 22.9*; 0%* (9)[2]

[1]Summing the values for SFDs (7) and MFDs (8).
[2]Assuming the 17% of the value provided for year 2010 for the entire Sweden, as 17% corresponds to the population share for VG.
[3]Assuming the 17% of the average of the value provided for years 2009 and 2011 for the entire Sweden.
[4] Summing the values for SFDs (7) and MFDs (8).

Figure 1 compares the share of the different energy carriers in the FEC of the buildings in the Swedish KASK region as obtained from the modelling and from statistics (18). For the Norwegian KASK region it was not possible to provide a similar comparison due to lack of statistical values.

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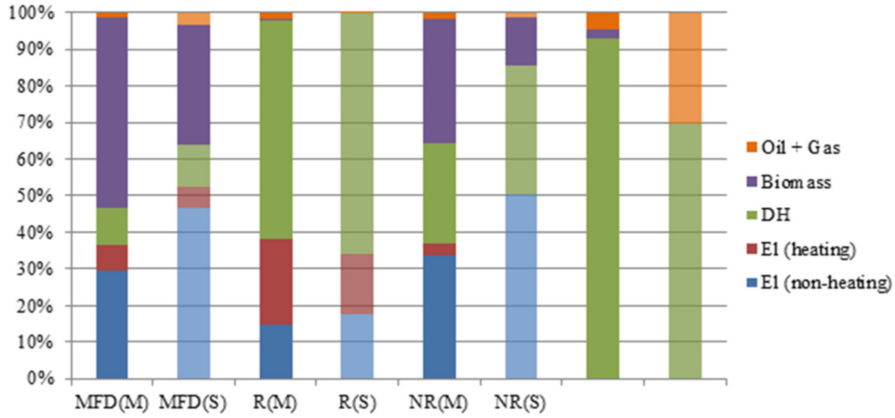

Figure 1. Comparison between modelled and statistical values of the share of the different energy carriers in the FEC of the buildings in the Swedish KASK region. M, modelled in this work, S, from statistics; R, residential; NR, non-residential; SFD, single-family dwelling; MFD, multifamily dwelling.

With respect to the Norwegian region, the results in this paper are still preliminary since work is still ongoing to improve the basis for the archetype buildings. Table 3 compares the preliminary model results for the entire Norwegian building stock and that of the Norwegian KASK region (in the reference year 2010) with corresponding data from statistics with respect to annual FEC, number of buildings and heated floor areas. The modelled FEC for KASK-region of Norway (17.8 TWh) is 10% higher than the corresponding value reported in statistics (16.0 TWh) (19). Nevertheless, in both the FEC and heated floor areas, the values are not directly reported in statistics, but have been calculated from the number of dwellings and the average FECs and heated floor areas of the different types of dwelling. For the entire Norway, the modelled FEC (49.6 TWh) is 6% higher than the corresponding value reported in international statistics (16.0 TWh) (20) (21), although it is 19% higher than what national statistics report (19). Similarly, the heated floor areas obtained in this work (which are calculated by multiplying the number of dwellings to the average energy consumption per dwelling given in national statistics) results in a substantial discrepancy on the distribution of the areas within the building subtypes (+40% for SDF and -80%) from the international statistics. The reason for the differences between the values reported in national statistics and those reported in international databases is not known.

Table 3. Comparison of the modelled and statistical data for the entire Norwegian building stock and the KASK region (in the reference year 2010) for annual FEC (TWh/yr), *number of buildings* (k) *and heated floor areas* (Mm^2). *The sources used for the comparison are specified in the table.*

Subsector	Final Energy Consumption		Number of dwellings		Heated floor areas	
	This work	From statistics; *deviation*	This work	From statistics; *deviation*	This work	From statistics; *deviation*
KASK_R	*17.8*	*16.0; +10%* (19)	*810.3*	*810.3; 0%* (16)	86.7	na
SFD	10.2	na	354.7	354.7*; 0%* (16)	*46.2*	na
RH	3.9	na	191.1	191.1*; 0%* (16)	*20.5*	na
MFD	3.7	na	264.5	264.5*; 0%* (16)	20.0	na
NO_R	49,6	46.5*; +6%* (20) 45.8*; +7%* (21)	2005.7	2005.7; *0%* (16)	220.8	257.3; -10% (21)[1]

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		40.3; *+19%* (16) [1]				
SFD	32,3	27,2; *+16%* (19) [1]	1058.4	1058.4; *0%* (16)	136.1	97.1;+40% (21) [1]
RH	9,2	7.8; *+15%* (19) [1]	441.1	441.1; *0%* (16)	46.5	na
MFD	8,1	5.3; *+34%* (19) [1]	506.2	506.2; *0%* (16)	38.2	155.6; -80%[2] (21) [1]

[1] Calculated by multiplying the number of dwellings to the average energy consumption per dwelling.
[2] Compared to the sum of RH and MFD obtained in this work.

According to SSB data for Norwegian households (19), the share of electricity and biomass in the household energy consumption is 77% and 15%, respectively. These values were found to be consistent with the values obtained in this work for whole Norway. No values have been found for the different building types or for the KASK region of Norway that could be compared with the fuel shares obtained in this work.

In summary, we have presented a preliminary analysis with the aim to provide a solid description of the building stock in two regions in Sweden and Norway. Although, the methodology for describing the building stock has previously been successfully applied to several countries, including Sweden there are still uncertainties when trying to “scale down” the building description to local region. Since the modelling methodology has already been satisfactorily validated, the uncertainties are attributed to the data available being scattered, inconsistent, uncomprehensive or protected, i.e. with the consequent difficulties to downscale the building-stock description and to validate the results of the modelling. Thus, ongoing work comprises refining the input data by applying additional sources of data as well as by understanding the deviation between the data in the different statistical sources applied. In general, there is a need for better energy relevant statistics in the building sector on a regional level, which would facilitate the assessment of ECMs of the building stock and, thereby, help monitoring the compliance with targets on energy savings and reductions in GHG emissions.

Conclusions

Descriptions of the regional building stocks in the South West of Sweden and the South East of Norway are provided together with a first validation of these descriptions. The validation is performed by comparing the FEC obtained from the modelling in this work (using ECCABS building-stock model) with available statistics. We conclude that there the uncertainty in the methodology applied is higher for the regions than for corresponding work on national level, which is primarily due to less data available for validation than what is available on the national level – the obvious level for official statistics. This represents a significant problem since regions often have clear targets on increased energy efficiency and emissions reductions and, lack of data makes it difficult to monitor if such targets are on the way to be fulfilled.

References

1. *Description of the European building stock through archetype.* Mata, É., Sasic Kalagasidis, A. and Johnsson, F. s.l. : 8th SDEWES Conference , 2013.

2. *A modelling strategy for energy, carbon, and costs assesments of buildings stocks.* Mata, Érika. 56, 2013a, Energy and Buildings, pp. 100-108.

3. Agency, Swedish Energy. *Facts and figures- Energy in Sweden 2011.* Eskilstuna, Sweden. : Swedish Energy Agency, 2011.
4. *Norwegian Water Resources and Energy Directorate (NVE), Annual Report.* 2009.
5. *Energy usage and technical potential for energy saving measures in the Swedish residential building stock.* Mata, Érika. 55, 2013b, Energy Policy, pp. 404-414.
6. Grundsell, Johanna. *Bottom-up description of the Swedish non-residential building stock - Archetype buildings and energy demand.* Göteborg : Chalmers University of Technology, Department of Energy and Environment, 2013.
7. STEM. *Energy statistics for one- and two-dwelling buildings in 2011.* Eskilstuna : Statens Energimyndighet (STEM), 2012a. ISSN: 1654-7543.
8. —. *Energy statistics for multi-dwelling buildings in 2011.* Eskilstuna : Statens Energimyndighet (STEM), 2012b.
9. —. *Energy statistics for non-residential premises 2011.* Eskilstuna : Statens Energimyndighet (STEM), 2012c. ISSN: 1654-7543.
10. Boverket. *Energi i bebyggelsen – tekniska egenskaper och beräkningar - resultat från projektet BETSI.* Karlskrona : Boverket, 2010.
11. SCB. Kalkylerat bostadsbestånd efter region och hustyp. År 1990 - 2012. [Online] 2014a. [Cited: 25 April 2014.] http://www.scb.se/sv_/Hitta-statistik/Statistikdatabasen/Variabelvaljare/?rxid=b098961b-4488-40be-8bd4-d180b7ad7a88&productcode=&menu=2&px_tableid=ssd_extern%3aBostadsbestandK.
12. —. Lägenheter i nybyggda hus efter region och hustyp. [Online] 2014b. [Cited: 22 April 2014.] http://scb.se/sv_/Hitta-statistik/Statistikdatabasen/Variabelvaljare/?px_tableid=ssd_extern%3aLagenhetNyKv&rxid=7e9d2f0b-1a49-4b0b-8a3f-cb25a034d5f0.
13. Thyvolt, M., et al., et al. *IEA SHC Advanced Housing Renovation by Solar and Conservation, Energy Analysis of the Norwegian Dwelling Stock.* 2009.
14. Méthode 3CL-DPE. Annex 1 in: Arrêté portant approbation de diverses méthodes de calcul pour le diagnostic de performance énergétique en France métropolitaine NOR : SOCU 06 10 563 A. s.l. : République Française, Ministère de l´emploi, de la cohésion sociale et du.
15. Norsk Standard NS 3031. *Calculation of Energy Performance of Buildings - Method and Data.* 2007.
16. https://www.ssb.no/statistikkbanken/selecttable/hovedtabellHjem.asp?KortNavnWeb=boligstat&CMSSubjectArea=bygg-bolig-og-eiendom&checked=true. [Online]
17. STEM. *Summary of energy statistics for dwellings and non-residential premises 2012.* Karlskrona : Statens Energimyndighet (STEM), 2013.
18. Statistics, Swedish. Slutanvändning av energi 2010 efter förbrukarkategori och bränsletyp. Sammanställningen.
19. http://www.ssb.no/husenergi/. [Online]
20. Commission, European. *Eurostat Database.*
21. Enerdata. *ODYSSEE Database.*
22. STEM. *Att tillägsisolera hus - fakta, fördelar och fallgropar.* s.l. : Energimyndigheten, 2009.
23. Mata, Érika and Kalagasidis, Angela. *Calculation of energy use in the Swedish housing.* Göteborg : Chalmers University of Technology, 2009. ISSN: 1652-9162.
24. Boverket. *Så mår våra hus - redovisning av regeringsuppdrag beträffande byggnaders tekniska utformning m.m.* Karlskrona : Boverket, 2009.
25. —. *Optimala kostnader för energieffektivisering - ...* Karlskrona : s.n., 2013.
26. Myhre, L. *Some Enivironmental and Economic Aspects of Energy Saving Measures in Houses (Doktor ingeniøravhandling)* . s.l. : Norwegian University of Science and Technology, 1995.
27. —. *Towards Sustainability in the Residential Sector. A study of Future Energy Use in the Norwegian Dwelling Stock.* s.l. : Norwegian Building Research institute, NBI Note 41, 2000. Building Technology. , 2000.

ISBN: 978-84-697-1815-5

28. Benejam, G. M. *Bottom-up characterisation of the Spanish building stock – Archetype buildings and energy demand, Master Thesis.* s.l. : Chalmers University of Technology, Göteborg, Sweden, 2011.
29. *Calculation of Energy Performance of Buildings - Method and Data.* s.l. : Norsk Standard NS 3031, 2007.

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Analysis of Indoor Environment Quality and Heating Energy Consumption by Building Retrofit for Energy Efficiency of the Public Building

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Abstract: *Remodeling of the buildings would be required for an improvement of the building energy rating system was enforced by the government in Korea. Especially, Korean government has promoted an old building remodeling project called 'Green Remodeling for Public Buildings'. In case of office buildings, for example, the remodeling is far more efficient than new construction in terms of time and cost. In fact, the remodeling can save energy and enhance occupants' work efficiency as well. Therefore, this study has analyzed the effects of remodeling on improvement of indoor environment and reduction of heating energy by measuring indoor environment and energy-saving performances before and after the remodeling of old public buildings. This study analyzed the improvement of indoor environment and reduction of cooling energy after the remodeling through measurement of indoor thermal environment and cooling energy consumption before and after the remodeling of public buildings.*

Key words: Indoor thermal environment, Public building, Retrofit, Energy saving

1. Intorduction

In Korea, it's been compulsory for all public buildings which are built since January 1, 2010 to acquire 1st grade in Building Energy Efficiency Rating. In fact, high level of energy-saving policies such as addition of energy-saving design conditions to review on the construction of local government buildings have been promoted. For public buildings, 'Regulations on Rationalization of Energy Utilization by Public Organization (Ministry of Trade, Industry and Energy Announcement No. 2013-71)' was enacted in July 2011, and energy consumption in public buildings has been checked (ex: Indoor air temperature limit (winter: 18℃, summer: 28℃) on a regular basis.

In addition, 'Announcement on Limitation of Energy Consumption (by Ministry of Trade, Industry and Energy)' was released in peak seasons (summer and winter), and energy consumption restriction policies such as mandatory reduction of power consumption and sequential energy consumption break by region have been operated.

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In old buildings, however, these policies have decreased work efficiency without considering occupants' particular working environment. To solve these problems, Korean government has promoted an old building remodeling project called 'Green Remodeling for Public Buildings'. In case of office buildings, for example, the remodeling is far more efficient than new construction in terms of time and cost. In fact, the remodeling can save energy and enhance occupants' work efficiency as well. Therefore, this study has analyzed the effects of remodeling on improvement of indoor environment and reduction of heating energy by measuring indoor environment and energy-saving performances before and after the remodeling of old public buildings.

2. Overview of the target building

The target building in this study is a 5-story public building with basement (8,843㎡ in gross floor area) in Korea, which was completed in 1997. It was constructed by satisfying the minimum requirements for thermal insulation and air-tightness performances according to 'Construction Act' at that time. Because of poor thermal insulation and air-tightness performances, its envelope was retrofitted in 2012 Table 1.

Tabla 1. Performance of Envelope system

Performance Criteria		Existing	Improvement	Target Performance
Curtain Wall	U value (W/㎡K)	4.0 More	1.2 Below	Insulation performance 70% more
	SHGC	0.7 More	0.25 Below	
Window	U value (W/㎡K)	4.0 More	1.2 Below	Insulation Performance 70% more
	SHGC	0.7 More	0.25 Below	
Wall	U value (W/㎡K)	4.0	0.27 Below	Insulation standard of Building Code Satisfaction

Figure 11 Before(left) and after(right) of the target building

3. Indoor thermal environment evaluation methods

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To analyze the improvement of indoor thermal environment and energy-saving performances after retrofiting during winter, indoor and outdoor air temperature and heating energy consumption in January 2012 and January 2014 were comparatively analyzed. For objective comparison, an equation of indoor temperature before and after the remodeling (y_i) and heating energy consumption (y_e) was derived with outdoor air temperature as variable (x). Indoor and outdoor air temperature was measured on the 5th floor of the building, and indoor and outdoor air temperature was comparatively analyzed during buisness hours(a.m 09:00~p.m. 18:00). Finally, it was evaluated the heating energy consumption.

4. Result

4.1 Analysis of indoor air temperature against outdoor air temperature

As a result of measuring the indoor and outdoour air temperature, temperature difference was about 20.5 ℃ before retrofit, while 23.3 ℃ after retrofit. Nevertheless outdoor air temperature higher in before retrofit, indoor air temperature after retrofiting was higher than before. Besiedes indoor air temeperature is maintained constantly without outdoor air temperature.

After measuring indoor temperature (y_i) against outdoor air temperature (x) before and after the retrofiting during business day, the following equations were derived: $y_{i\text{-before}}$=0.0287x +20.437, $y_{i\text{-after}}$=0.031x+19.918 (after the remodeling).

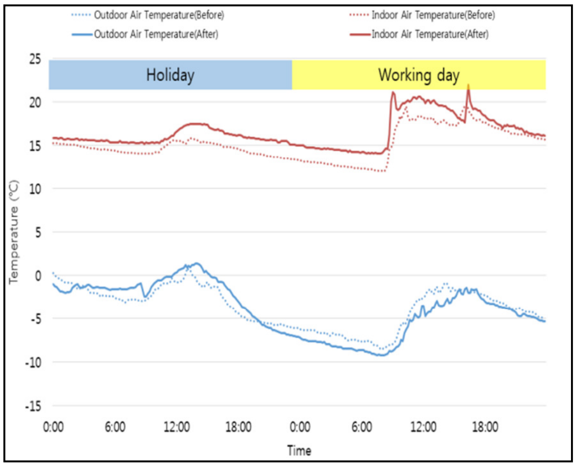

Figure 12 Indoor air and outdoor air temeperature in holiday and working day

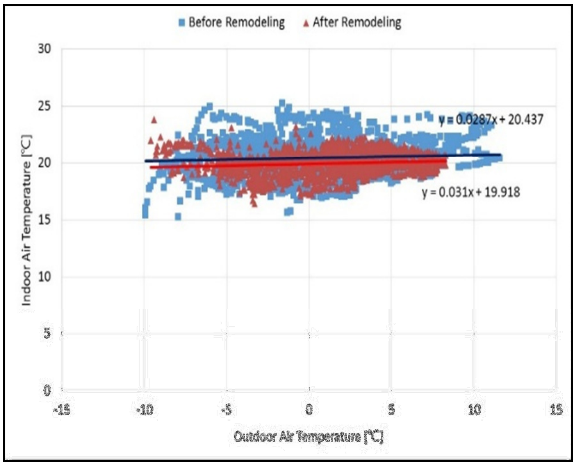

Figure 13 Indoor air temperature by outdoor air temperature

4.2 Heating energy consumption after remodeling

After analyzing heating energy consumption (y_e) against outdoor air temperature during business hours, the following equations were derived: $y_{e\text{-before}} = -0.0506x+1.2723$, $y_{e\text{-after}} = -0.029x+0.9016$ According to analysis of heating energy consumption after the retrofiting based on the equation above, heating energy consumption decreased by about 32 % after the remodeling when the outdoor air temperature was –10 to 0℃.

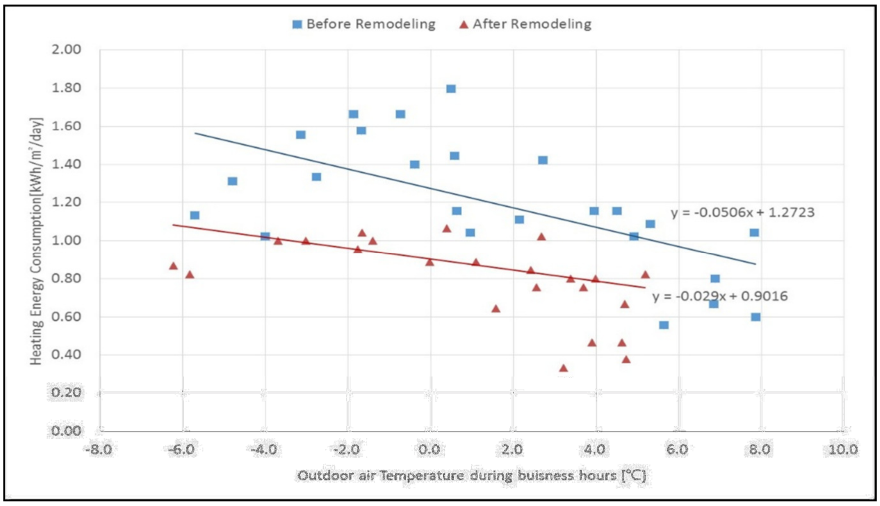

Figure 14 Energy consumption for cooling by outdoor air temperature

According to analysis of indoor air temperature and heating energy consumption against outdoori temperature during business hours, heating energy consumption was decreased 32 % after the remodeling to maintain indoor air temeprature 18~20 ℃. Therefore, it appears that the remodeling of old buildings would be able to reduce energy consumption and enhance occupants' work efficiency through the improvement of indoor environment.

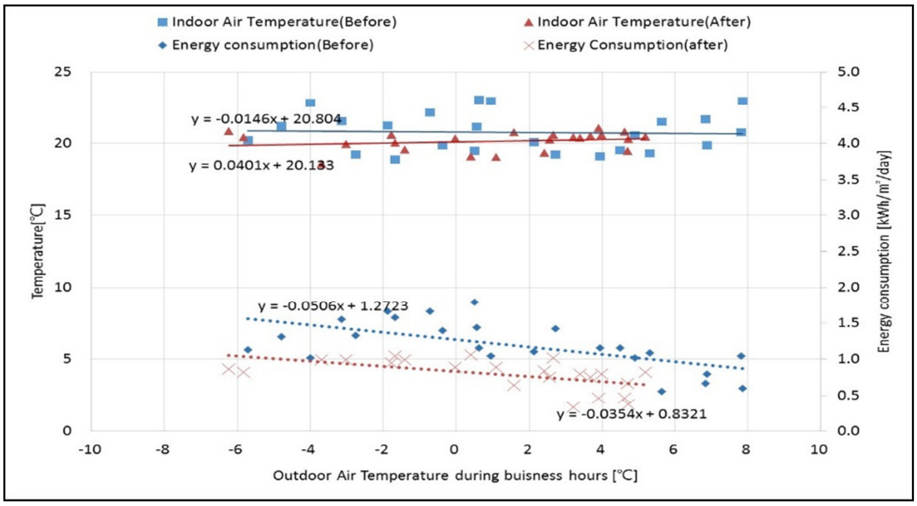

Figure 15 Indoor air temperature and heating energy consumption by outdoor air temeperature

5. Conclusion

This study analyzed the improvement of indoor environment and reduction of heating energy consumption after the retrofiting. through measurement of indoor thermal environment and heating energy consumption in public buildings and found the followings:
1) Indoor air temperature after retrofit is similar to indoor air temeperature before retrofit. And indoor air temeperature is maintained constantly without outdoor air temperature.
2) The heating energy consumption decreased about 32 % by outdoor air temperature after the retrofiting.
After the retrofiting, heating energy consumption decreased, and indoor temperature is maintained constantly without outdoor air temepertature. Therefore, it was confirmed that the remodeling improved indoor environment and reduced energy consumption. There will be a further study on the improvement of indoor thermal environment and reduction of cooling energy consumption during summer and post occupancy evaluation.

References

1. Son, J. H., Kim, S. Y., A Study on Energy Savings way of Domestic Public Buildings, 2011 summer Conference of Air- Conditioning and Refrigeration Engineering, pp. 625-630.
2. Lee, J. B., Kim, S. Y., Choi, K. H., Park, T. Y., Lee, K. H., An Analysis for Recognizing the priority of Indoor Environmental Factors in Office Building, 2002 Conference of Korea Institute of Ecological Architecture and Environment, pp. 99-104

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Improving the thermal performance of commercial buildings envelope

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Abstract: *Thermal performance of buildings is a key factor regarding sustainability. The goals of "Europe 2020" will only be achieved if we rethink built environment and define clear intervention's strategies to improve its performance.*

One of the typologies less studied are commercial buildings. However, this type of construction represents large open space areas marked by the energy consumption for thermal comfort, lighting needs and consumer goods refrigeration.

This paper presents the analysis of thermal performance of several constructive solutions of buildings envelope (façades and roofs) used in commercial spaces, namely supermarkets. The analysis was carried out taking into account a comprehensive survey of constructive solutions adopted in Portugal

The thermal analysis of these buildings envelope was performed according the Portuguese Code and has permitted the comparison between the actual thermal performance and the expected performance if reference values of the Code were adopted, After this analysis it was possible to classify the solutions according to their characteristics, in order to improve its performance with an optimized thermal balance.

Sustainable construction, thermal behaviour, building envelope, supermarkets

1. Introduction

Climate change represents one of the greatest environmental challenges for any company. Climate variability and extreme events can affect commercial activity; however, this sector favours these climate changes, since all operations related to sales require the consumption of energy and transport fuels, as well as CO_2 emissions.

When focusing on retail sector, and according to the latest indicators [1], this one is the second largest energy consumer, and, when referring to food retail, these numbers are easily understandable by the dimension of the buildings that is required to implement super and hypermarkets, and its open-space concept.

Supermarkets have been classified as service buildings, providing a generic and unclear attention to this specific type of building and its real needs, which allows us to recognize in this area an unfilled gap and a considerable potential to study and research.

In general, the three greatest energy consumers in a supermarket building are refrigeration, HVAC and lighting. Through the sustainability reports of the largest retail companies, it is possible to recognize the investment made in more efficient refrigeration equipment and lighting systems, with the incorporation of case doors and even the introduction internal gains into the heating system or the introduction of LED lighting, for example. All these measures have in common that they can be implemented quickly and easily, without requiring major changes to supermarkets operations.

Therefore, the construction of supermarket buildings and the optimization of their energy efficiency, from the point of view of sustainable architecture and construction, have been less studied. However, the dimensions of these buildings, either in area or in volume, and the fact that they must maintain a comfortable temperature for the customer, constant through the day and through the year, have imposed our special attention to the envelope of supermarket buildings.

The main purpose of this paper is to analyse a set of fifteen supermarket buildings of one of the biggest Portuguese retail companies, in order to achieve the optimal solution for supermarkets construction systems, focusing in the envelope thermal insulation.

It is intended to achieve the optimal thermal response of the envelope, adjusting the buildings to their real needs, and leaving to efficient equipment what construction cannot answer.

2. Methods and procedures

The methodology used in this work is based on the analysis of a number of supermarkets with several locations and dimensions, trying to realize the potential of improvement of building construction systems adopted, in order to reduce their energy consumption for heating, ventilation and air conditioning.

The retail group holds three supermarket insignia, designed for three main groups of target consumers:

<u>Type C</u>: hypermarkets, which have dimensions above 3500m^2, for large scale consumers and shopping for long term; they are usually deployed in large urban centers and associated to shopping malls;

<u>Type M</u>: intermediate-sized supermarkets, usually between 1500 m^2 and 3500m^2, deployed in small or medium cities; they have a stand-alone format, with a set of offerings that aim to fulfil the needs of the populations, as other types of stores belonging to the same company;

<u>Type BD</u>: supermarkets with dimensions below 1500m^2, based on neighbourhood convenience stores; they are usually installed in existing buildings in consolidated urban areas or in commercial galleries of residential buildings.

The analysis to each supermarket resulted in the need to understand the thermal behaviour brought by the building systems adopted.

It should be referred also that, beyond the scope of this paper, several alternative type and thickness of insulation were tested, for each system, according to the geographical location of each supermarket and the thermal requirements brought by the more recent Portuguese

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legislation.

The best ratio between heat transfer coefficient (U) and the shorter pay-back follows the optimal solution for each case, with conditions to extrapolate the results for each Climate Zone and, thus, to produce recommendations for the use of thermal insulation in each supermarket building system.

3. Case Studies

In Table 1 are systematized the constructive characteristics of the case study sample (15 supermarkets: commercial area of 33.000 m^2 with 4.000 m^2 of external walls and 19.000 m^2 of external roofs) that may influence the thermal performance of buildings. It was realized that there is a clear concern about the layout of the sales area, for operational reasons, being relatively stable for each insignia. However, it was not find a rule to define ceiling heights or glazing areas and, therefore, the ratio between natural lighting and store area/volume.

Table 1: Technical and constructive data of the analysed supermarkets

STORE	STORE AREA (m^2)	CEILING HEIGHT (m)	STORE VOLUME (m^3)	GLAZING AREA (m^2)	FAÇADE AREA IN CONTACT WITH THE EXTERIOR (m^2)	ROOF AREA IN CONTACT WITH THE EXTERIOR (m^2)	FORM FACTOR	AREA IN CONTACT WITH UNHEATED AREAS (m^2)
C.1	3 746,61	4,54	17 009,61	0,00	467,98	3 746,61	0,25	457,04
C.2	8 732,11	8,60	75 096,15	0,00	0,00	0,00	0,00	1 226,70
C.3	2 897,85	8,55	24 776,62	0,00	257,27	2 897,85	0,13	943,07
M.1	2 100,00	6,33	13 293,00	0,00	214,59	2 100,00	0,17	468,67
M.2	2 179,50	5,75	12 532,13	184,04	304,98	1 273,57	0,14	478,23
M.3	2 176,56	6,35	13 821,16	0,00	0,00	2 176,56	0,16	612,08
BD.1	1 301,31	7,00	9 109,17	272,98	210,46	0,00	0,05	643,77
BD.2	833,00	4,40	3 665,20	83,08	181,02	0,00	0,07	388,04
BD.3	1 363,17	3,69	5 030,10	57,91	22,95	151,61	0,05	223,76
BD.4	1 336,74	6,45	8 621,97	138,20	421,57	1 336,74	0,22	520,06
BD.5	1 342,75	7,70	10 339,18	0,00	0,00	1 342,75	0,13	715,56
BD.6	1 289,00	7,12	9 177,68	131,13	417,02	1 289,00	0,20	536,49
BD.7	906,15	5,10	4 621,37	84,05	421,82	0,00	0,11	127,50
BD.8	1 064,50	5,00	5 322,50	105,09	504,90	1 064,50	0,31	209,15
BD.9	1 380,03	7,85	10 833,24	116,00	550,29	1 380,03	0,19	793,79

This analysis identified the building systems adopted in roofs and façades, revealed common to the three insignia. The major difference between them lies only in the area and volume of the store. Since there is no clear reason to justify the separation per insignia, it was profitable to group all stores in a common study, believing that a larger sample will bring more consolidated results.

The building construction systems found in this survey include the following three types of façades (F1, F2, F3) and two types of roofs (R1, R2) (see Tables 2 and 3):

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Type F.1: ETICS system on a single concrete or brick masonry wall, in cases of implantation in existing spaces or commercial galleries. The insulation used in the system varies in type and size, with no defined rule;

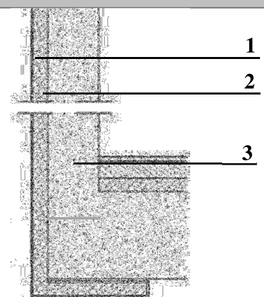
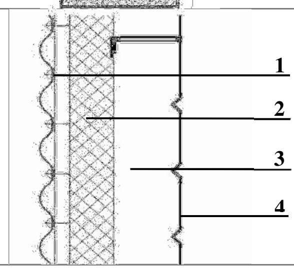
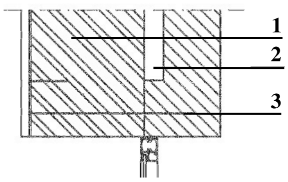
Type F.2: Lightweight construction in sheet metal pavilion-type building, in cases built from scratch and especially in stand-alone format. The insulation presents diverse thickness and materials, without a rule;

Type F.3: Construction of a double masonry wall, in cases of rehabilitation of existing and notable buildings, with the constitution of an internal brick wall and maintaining the existing external wall. There is no thermal insulation found in these cases;

Type R.1: Most roofing systems consist of a lightweight structure coated with sandwich panel in trapezoidal sheet metal;

Type R.2: in existing buildings there is the external insulation of the existing support, covered with a PVC membrane.

Table 2: Overview of building systems of existing façades

TYPE	FAÇADE SYSTEMS	SECTION	
F.1	EXTERNAL THERMAL INSULATION SYSTEM SUPERMARKETS: C.1 M.2 BD.2 BD.3 BD.7		1. Reinforced plaster 2. ETICS 3. Supporting wall in concrete block or brick masonry
F.2	LIGHT STEEL CONSTRUCTION SYSTEM SUPERMARKETS: C.3 M.1 BD.1 BD.4 BD.6 BD.8		1. External wavy sheet, painted grey 2. Thermal insulation 3. Airbox 4. Inner metal sheet
F.3	DOUBLE MASONRY WALL SYSTEM SUPERMARKETS: BD.9		1. External wall in stone masonry 2. Airbox 3. Inner wall in brick masonry

Natural lighting is usually obtained by using tubular daylighting roof devices, whose dimension and number don't reveal any clear rule. This is particularly important, as the same type of solar tube is found in stores with diverse dimensions, varying significantly its

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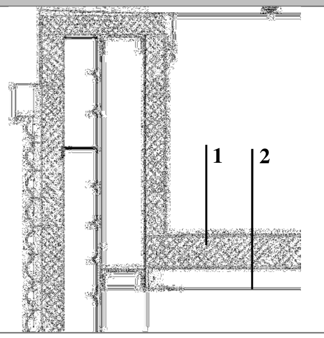
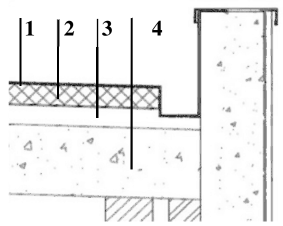
efficiency. There is no information about glazing types used.

Table 3: Overview of building systems of existing roofs

TYPE	ROOFING SYSTEMS	SECTION	
R.1	LIGHT SYSTEM IN SANDWICH PANEL SUPERMARKETS: C.1 C.3 M.1 M.2 M.3 BD.3 BD.4 BD.5 BD.6 BD.8		1. Sandwich panel: external metal sheet + thermal insulation + inner metal sheet 2. Support frame
R.2	INSULATION SYSTEM ON EXISTING SLAB SUPERMARKETS: BD.9		1. Outer membrane in PVC 2. Thermal insulation 3. Shape layer 4. Existing slab

4. Analysis of the energy performance of the external envelope supermarket buildings

The lack of rules defining the constitution of these building systems has motivated a more detailed examination of the factors that may play a key role in thermal behaviour of the buildings, like the thermal insulation.

Table 4: Losses through façades

STORE	STORE AREA (m^2)	FAÇADE AREA IN CONTACT WITH EXTERIOR (m^2)	FAÇADE SYSTEM TYPE (Table 2)	U FAÇADE ($W/m^2.{}^{o}C$)	CLIMATIC ZONE [2]	Uref ($W/m^2.{}^{o}C$) [3]	DEGREE-DAYS (ºC.days)	HEAT TRANSFER BY TRANSMISSION (kWh.year)	MAXIMUM HEAT TRANSFER ACCORDING TO Uref	OVER LOSSES
C.1	3 746,61	467,98	F.1	0,50	I_1	0,70	1 184,10	6 649,62	9 309,47	-28,57%
C.2	8 732,11	0,00	-		I_1	0,70	1 115,20			
C.3	2 897,85	257,27	F.2	2,86	I_1	0,70	783,60	13 837,60	3 386,83	308,57%
M.1	2 100,00	214,59	F.2	0,56	I_2	0,60	1 723,40	4 970,44	5 325,47	-6,67%
M.2	2 179,50	304,98	F.1	0,50	I_2	0,60	1 321,40	4 836,01	5 803,21	-16,67%
M.3	2 176,56	0,00	-		I_1	0,70	1 037,30			
BD.1	1 301,31	210,46	F.2	0,65	I_2	0,60	1 455,90	4 779,98	4 412,29	8,33%
BD.2	833,00	181,02	F.1	0,56	I_1	0,70	928,20	2 258,23	2 822,78	-20,00%
BD.3	1 363,17	22,95	F.1	0,57	I_1	0,70	1 026,80	322,37	395,89	-18,57%
BD.4	1 336,74	421,57	F.2	0,56	I_1	0,70	1 219,60	6 910,13	8 637,67	-20,00%
BD.5	1 342,75	0,00	-		I_3	0,50	1 896,00			
BD.6	1 289,00	417,02	F.2	0,56	I_1	0,70	1 179,60	6 611,36	8 264,20	-20,00%
BD.7	906,15	421,82	F.1	0,56	I_1	0,70	928,20	5 262,21	6 577,76	-20,00%

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BD.8	1 064,50	504,90	F.2	0,56	I_1	0,70	1 115,20	7 567,59	9 459,48	-20,00%
BD.9	1 380,03	550,29	F.3	1,17	I_1	0,70	1 138,00	17 584,54	10 520,66	67,14%

Comparing the U values of wall solutions with its reference value according to Portuguese Thermal Code established for each climatic zone, becomes notorious the amount of energy that, in some cases, could be saved only by improving the building solution of the façades (Table 4). A similar analysis was done with roofing solutions and the values referred in the code and are shown in Table 5.

Table 5: Losses through roofs

STORE	STORE AREA (m^2)	ROOF AREA IN CONTACT WITH EXTERIOR (m^2)	ROOFING SYSTEM TYPE (Table 3)	U ROOF ($W/m^2.ºC$)	CLIMATIC ZONE [2]	Uref ($W/m^2.ºC$) [3]	DEGREE-DAYS (ºC.days)	HEAT TRANSFER BY TRANSMISSION (kWh.year)	MAXIMUM HEAT TRANSFER ACCORDING TO Uref	OVER LOSSES
C.1	3 746,61	3 746,61	R.1	0,40	I_1	0,50	1 184,10	42 589,06	53 236,33	-20,00%
C.2	8 732,11	0,00	-		I_1	0,50	1 115,20			
C.3	2 897,85	2 897,85	R.1	0,49	I_1	0,50	783,60	26 704,08	27 249,06	-2,00%
M.1	2 100,00	2 100,00	R.1	0,49	I_2	0,45	1 723,40	42 561,09	39 086,71	8,89%
M.2	2 179,50	1 273,57	R.1	0,49	I_2	0,45	1 321,40	19 790,85	18 175,27	8,89%
M.3	2 176,56	2 176,56	R.1	0,49	I_1	0,5	1 037,30	26 551,09	27 092,95	-2,00%
BD.1	1 301,31	0,00	-		I_2	0,45	1 455,90			
BD.2	833,00	0,00	-		I_1	0,50	928,20			
BD.3	1 363,17	151,61	R.1	0,49	I_1	0,50	1 026,80	1 830,72	1 868,08	-2,00%
BD.4	1 336,74	1 336,74	R.1	0,49	I_1	0,50	1 219,60	19 172,19	19 563,46	-2,00%
BD.5	1 342,75	1 342,75	R.1	0,49	I_3	0,40	1 896,00	29 939,24	24 440,20	22,50%
BD.6	1 289,00	1 289,00	R.1	0,49	I_1	0,50	1 179,60	17 881,13	18 246,05	-2,00%
BD.7	906,15	0,00	-		I_1	0,50	928,20			
BD.8	1 064,50	1 064,50	R.1	0,49	I_1	0,50	1 115,20			
BD.9	1 380,03	1 380,03	R.2	0,49	I_1	0,50	1 138,00	18 468,78	18 845,69	-2,00%

The reference values of heat transmission for housing buildings are more severe than the reference values for commercial buildings; according to the Portuguese codes these value have an increase of about 30% for facades and 20% for roofs.

If we cross the solutions with the code exigencies according to the climatic zone, it is possible to define the more accurate solutions to answer to the exigencies in each case. This relation is presented in Table 6.

Table 6: Adequacy of façades and Roofs solutions vs climatic zones

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			Climatic Zones		
			I_1	I_2	I_3
Solutions	Facades	F.1	✓	✓	✓
		F.2	✓	✓	●
		F.3	●	●	●
	Roof	R.1	✓	●	●
		R.2	✓	●	●

The analysis of Table 4 and 5 clear shows that high energy savings could be achieved if the choice of the building solutions match, for each climatic zone, the solutions presented in Table 6. Where this is not observed, over losses range in walls is from 8% to 309% and over losses range in roofs is from 9% to 23%.

Since the insulation level is quite low (see U-value for roofs and façades on table 4 and 5), we have tested a general increase of 4 cm for the thickness of insulation boards in all buildings. This could lead to an annual energy saving more than 130.000 KWh/year without a considerable change of the construction system, what means that the increase of cost depends only on the insulation price. For current values, the pay-back of this solution is estimated in about 10 years.

5. Conclusions

The improvement of the thermal performance of retail buildings envelope (roofs and facades) is quite relevant in terms of economical and energy savings. Taking into account this case study of 15 supermarkets in Portugal, it was found that the number of different building systems is limited but the different types are generally adopted without any rule concerning the different climatic zones of the country.

Some preliminary measures for a better performance of these buildings are now quite clear: to avoid building solutions not recommend for the specific climate zone and a slight increase of insulation thickness, eventually without changing the building system. These measures will reduce the energy losses through the external envelope about 40% with a pay-back about 10 years. The actual scope of this research project is oriented for testing other building systems that can lead to the same energy saving with a better pay-back period.

6. Acknowledgements

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7. References

[1] Pordata (2012): *Electricity consumption: total and by sector of economic activity* (retrieved 16.05.2014 from http://www.pordata.pt/en/Portugal/Electricity+consumption +total+and+by+sector+of+economic+activity-1125)

ISBN: 978-84-697-1815-5

[2] Despacho n.º 15793-F/2013: Parâmetros para o Zonamento Climático do SCE – Sistema de Certificação Energética – Decreto-Lei n.º118/2013 de 3 de Dezembro (Portuguese Law - Climatic Zones Parameters according to the Energetic Certification System).

[3] Portaria n.º 349-D/2013: Regulamento do Desempenho Térmico de Edifícios de Comércio e Serviços (RECS) – Sistema de Certificação Energética – Decreto-Lei n.º118/2013 de 3 de Dezembro (Portuguese Law - Commercial and Services Buildings Thermal Performance according to the Energetic Certification System).

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Thermal Performance Analysis Of Un-Insulated And Owner Insulated Masonry Residential Buildings In Northwestern Mexico Using State-Space Simulation And Lumped Parameter Modeling

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Abstract: *A simplified lumped capacitance model for three building cases was developed to study the effect of insulation placement on thermal performance of the building envelope. The three cases are uninsulated concrete masonry construction, owner insulated building with insulation on the outside of the envelope, and a building with insulation on the inside of the envelope. The prototype building is a typical mid-range developer constructed residential building in Northwestern Mexico.*

The lumped capacitance model was implemented in state-space form and simulated using a commercially available mathematical package. Only transmission heat gains driven by air temperature difference were considered during the simulations, under free-running conditions, as well as under traditional on-off air conditioning control. Simulation results show a better indoor temperature profile for the outside insulated building, but with higher a/c energy consumption than the building insulated on the inside.

Keywords: Lumped Capacitance, State Space Simulation, Transient Thermal Performance, Construction Methods

Introduction

Midrange houses in northwestern Mexico are typically un-insulated in order to make them more affordable to the public. The typical developer built house in the region is a $75m^2$ two-story masonry building with flat concrete roof. Extreme outdoor temperatures in the region require heavy air conditioning usage in order to maintain comfortable indoor conditions for at least 5 months of the year. In order to decrease electricity consumption associated with air conditioning use, and help maintain comfortable indoor conditions, homeowners typically insulate their houses by adding 50mm thick rigid polystyrene insulation to the outside walls and roof, and covering the insulation with an appropriate material, like stucco or gypsum board. Although insulation could be added to the outside or to the inside of the building, insulation on the outside of the building is the most common in the region as these homes are commonly insulated after the building is occupied.

In addition to installing insulation, occupants try to decrease their electricity consumption by shutting-off the cooling equipment when the building is unoccupied; or when the outdoor temperature drops to more comfortable levels. As a consequence of shutting off the a/c, indoor temperature increases causing a cooling pickup load for the air conditioning equipment when the equipment is restarted. The indoor temperature variation, and corresponding cooling pickup load depends on the thermal storage of the building, and the relative position of the insulation with respect to the thermal mass of the buildings.

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Most cooling energy consumption calculations for residential construction in hot climates are based on steady-state or near steady-state heat transfer conditions with constant indoor air temperature maintained by the cooling equipment during the day. Under steady-state conditions, position of the insulation has no effect on energy calculations as storage and transient effects are neglected. While steady-state methods of energy calculation are simple and relatively accurate for most residential application, they are not capable of dealing with transient effects, or accurately describing the thermal behavior of buildings with thermal storage, or with varying indoor temperatures. Lumped capacitance models have been shown previously [1] to be suitable for short term transient analysis for building heat flow.

State-space computer simulations with lumped parameter models are being used to compare the thermal performance and cooling equipment energy use of three model concrete-block houses over a typical cooling season: a stock un-insulated building, a building with outside insulation, and building insulated on the inside. It is generally assumed that both insulation installations methods will provide the same thermal performance and cooling energy savings, and the purpose of this work is to determine if this assumption is valid for this type of buildings.

Building and Region Description

The typical residential building in newer mid-range developments is approximately 75m^2 two-story building. The building, as delivered by the developer, is made of uninsulated concrete masonry walls over on-grade concrete slab floor and flat concrete slab roof. The walls are initially covered with painted stucco on the outside, and painted plaster on the inside. Fenestration covers approximately 25% of the total envelope surface, and is limited to the front and back walls of the building. Sidewalls lack windows, as the distance between adjacent buildings is usually less than a meter. Figure 1 shows a picture of a sample residential building representative of the model considered in this work. The figure also shows a detail of the owner added rigid insulation after occupation. The insulation is 50mm of expanded polystyrene covered with gypsum board and plaster on the outside.

The building HVAC system is typically composed of two mini-split air conditioning units, with no heating system. The unit's size varies between 1-1/2 and 2 ton depending on the installer recommendations. Due to the high electricity cost in the region, the building occupants only operate the a/c units when they are home, and the indoor temperature is too high for comfort, typically in the afternoons and early evenings.

Although the building is effectively a two-zone system, for the purpose of this work it would be analyzed and simulated as a rectangular single zone building with the following simplifying assumptions:

- The walls and roof have the same overall thermal conductivity and heat capacity values;
- Heat gain and loss through the floor and foundation are negligible;
- The walls and roof have the same overall thermal conductivity and heat capacity values;
- Heat gain and loss through the floor and foundation are negligible;

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Figure 1 Sample Masonry Residential Building and Owner Installed Insulation Detail

- Internal heat gains and infiltration and ventilation gains are not considered in the model;
- Finally, due to the extensive use of window shading and the relatively small amount of fenestration relative to the surface area of the envelope, direct solar gains are also neglected during the simulation and modeling.

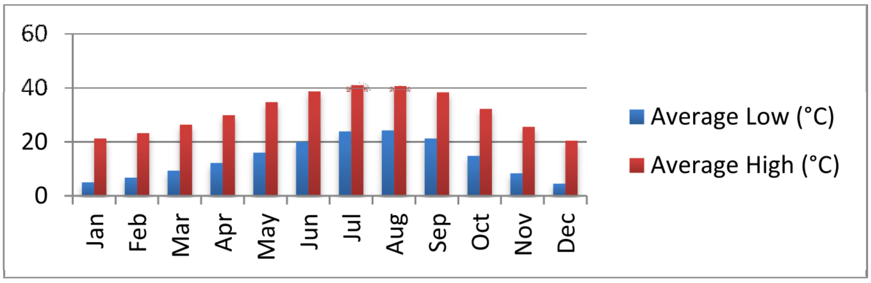

Figure 2 Monthly Averages Low and High Temperatures in Northwestern Mexico

Figure 3 Northwestern Mexico Region Map

The climate in the northwestern area of Mexico under consideration is hot and arid, with high ambient temperatures for five to seven months of the year (Figure 2). The region extends north from the Tropic of Cancer to the US border, and includes most of the Baja California

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peninsula (pacific coastal areas have a Mediterranean temperate climate) and the Sonoran desert in the mainland west of the Sierra Madre Occidental mountain range (Figure 3 above).

Mathematical Model

The simplified building described previously is modeled following the lumped capacitance method described in [2] which uses a electrical circuit equivalent to represent the thermal mass and thermal resistance (conductivity) of the building structure and the indoor air. Figure 4 shows the circuit network resulting from modeling the building envelope as a single thermal mass, with thermal resistances distributed around that mass to represent transmission heat flow paths from and to the outdoor air and indoor air space. The circuit network contains two sources, a temperature source modeling the outside air temperature, and a heat flow source that models the heat removed from the indoor environment when the air conditioning unit operates. The air conditioning unit operates under traditional on-off thermostat control.

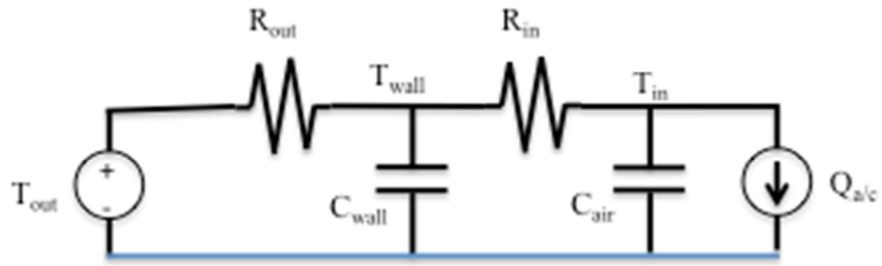

Figure 4 Simplified Building Lumped Capacitance Network Circuit Model

The circuit network in the above figure can be represented mathematically as a linear state-space system with two state variables: the envelope internal temperature (T_{wall}), and the indoor air temperature (T_{in}); and two input signals: the outdoor air temperature, and the air conditioner unit heat flow rate. Using matrix notation, the state-space equations resulting from energy balances around each internal temperature node can be expressed as

$$\begin{bmatrix} \dot{T}_{wall} \\ \dot{T}_{in} \end{bmatrix} = \begin{bmatrix} -\frac{1}{C_{wall}R_{in}} - \frac{1}{C_{wall}R_{out}} & \frac{1}{C_{wall}R_{in}} \\ \frac{1}{C_{space}R_{in}} & -\frac{1}{C_{space}R_{in}} \end{bmatrix} \begin{bmatrix} T_{wall} \\ T_{in} \end{bmatrix} + \begin{bmatrix} \frac{1}{C_{wall}R_{out}} & 0 \\ 0 & -\frac{1}{C_{air}} \end{bmatrix} \begin{bmatrix} T_{out} \\ \dot{q}_{a/c} \end{bmatrix}$$

$$y = \begin{bmatrix} 0 & 1 \end{bmatrix} \begin{bmatrix} T_{wall} \\ T_{in} \end{bmatrix} \qquad [1]$$

The values used for the building heat capacitances and thermal resistances are presented in Table 1 below for the three case buildings investigated: uninsulated structure, building with outside insulation, and building with inside insulation. These values were calculated assuming an exposed building envelope surface area of $139m^2$, an indoor volume of $156m^3$, and the building material thermal properties presented in Table 2. The overall building thermal resistances are obtained by adding the resistances of the individual material layers, including indoor and outdoor air-surface resistances, for each of the building conditions considered.

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Building Type	***R_{out} (K/kW)***	***C_{wall} (kJ/K)***	***R_{in} (K/kW)***	***C_{space} (kJ/K)***
Uninsulated	*1.08*	*45560*	*1.73*	*189*
Outside Insulation	*11.2*	*45560*	*1.73*	*189*
Inside Insulation	*1.08*	*45560*	*11.8*	*189*

Table 1 Lumped Capacitance Model Component Values used for the State-Space Model of Building

Building Material	***Thermal Resistance (Km^2/W)***	***Heat Capacity (kJ/m^3K)***
200mm Concrete/Concrete Block	0.2	1411
15mm Stucco	0.02	1562
15mm Gypsum Plaster	0.02	1411
50mm Expanded Polystyrene	1.4	19.2
Indoor Air Surface Resistance	0.12	-
Outdoor Air Surface Resistance	0.03	-
Indoor Air	-	1.21

Table 2 Thermal Properties of Air and Construction Materials used in Study Building.

Simulation Results

The state-space models for the uninsulated buiding and the two types of insulated buildings were implemented using a commercially available mathematical programming package, and the simulations ran for the case of free running building (Figure 5), that is with the air conditioning off; and for the case of the buildings with the air conditioning unit running continuously under traditional On/Off control (Figure 6). The indoor temperature set point was 25°C, and the air condition unit had a cooling capacity of 3kW.

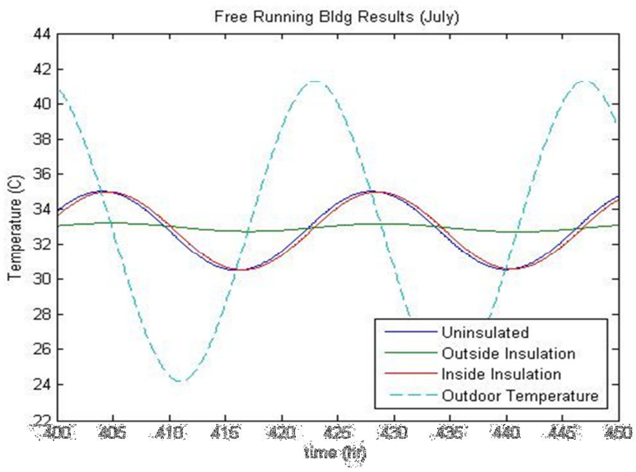

Figure 5 Free Running Building Air Temperatures for the Three Buildings Types

All the simulations were run using the outdoor air temperature data for the US California's Imperial Valley County [3] located across the border from the Mexican city of Mexicali. The two regions share the same rugged climate, but the American area had readily available data.

Figure 5 shows that under a free running building, indoor temperatures were lower during the daytime when outside insulation was used. The temperature profile with inside insulation resulted in temperature profile that tracked that of the non-insulated building with a small time delay. Figure 6 also shows that the building with outside insulation presented a better indoor temperature profile than the building with inside insulation, however with a larger number of temperature swing cycles.

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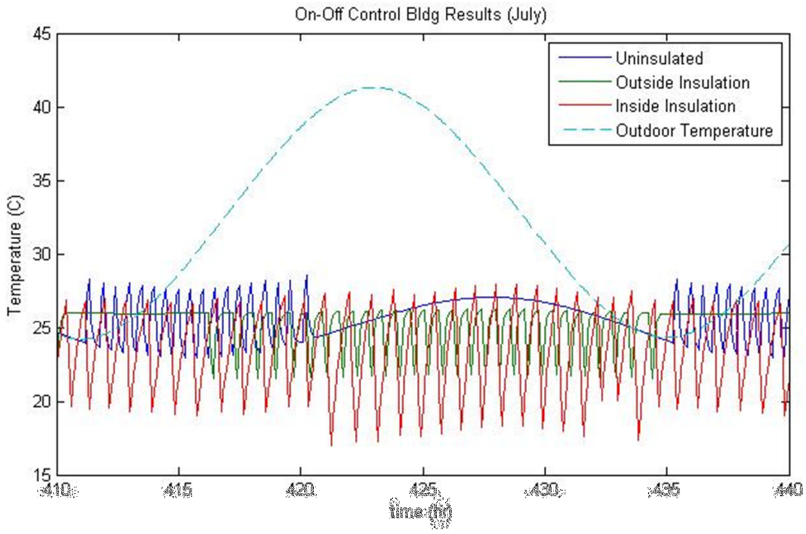

Figure 6 Indoor Temperatures for the Three Buildings Types under On-Off Air Conditioner Control

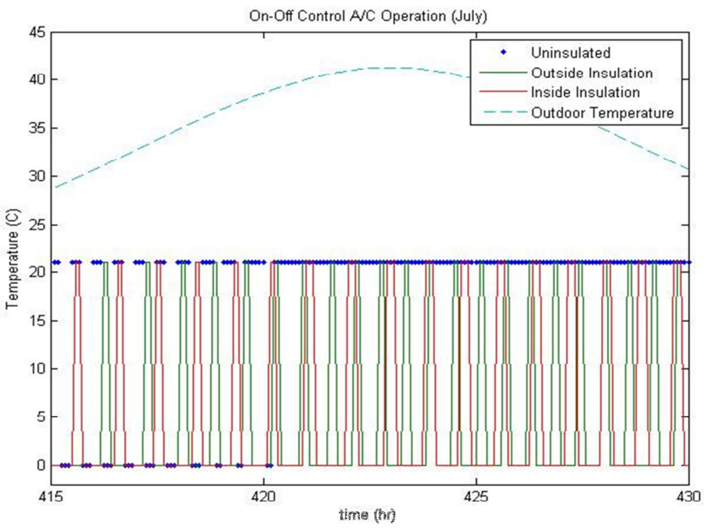

Figure 7 Air Conditioner Run Profile for a Sample Day in July. A/C operation plots are not to scale

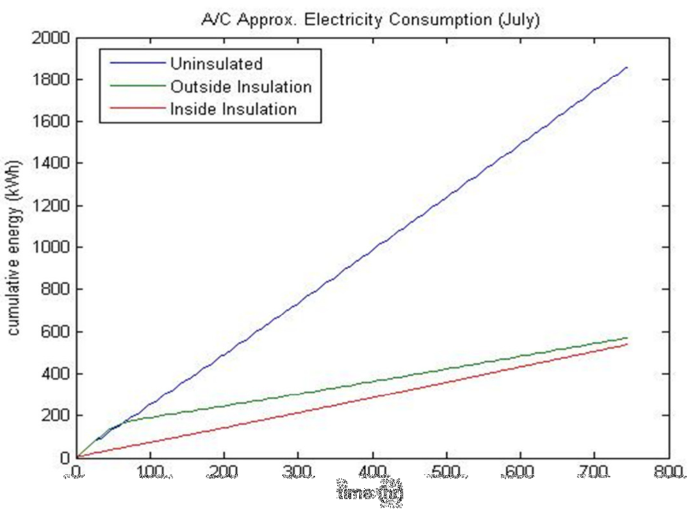

Figure 8 Air Conditioning Unit Accumulative Electricity Consumption in July for the Three Building Types

Figure 7 shows the operation of the air conditioning unit for the three building types. Both insulated buildings show a similar operation profile, but the uninsulated building profile shows that the 3kW unit is not big enough to handle the cooling load of the building.

Finally, Figure 8 shows the total energy consumption by the air conditioning unit for the three case buildings during the month of July. It can be seen from the graph, that the building insulated on the inside presented lower energy consumption than the building insulated on the outside. As expected, the building without insulation consumed significantly more energy than any of the insulated buildings.

Conclusion

The state-space models for three buildings were developed using simplified lumped capacitance modeling: a concrete uninsulated building, a concrete building insulated on the outside of the envelope using rigid polystyrene insulation, and the same building insulated on the inside of the envelope. Simulation of the simplified building structure focused only on transmission heat gains through the envelope, neglecting direct solar gains as well as gains associated with air and moisture movement.

Results from the computer simulations suggested that the building insulated on the inside would use the lowest amount of cooling energy during the hottest month of the year, however the energy consumption difference between the two insulated buildings might not be enough to justify and indoor insulation installation versus a less intrusive outdoor installation.

Further work is need to incorporate the neglected heat gains, in particular solar gains, into the model and simulation to provide a more conclusive performance comparison between the two insulation installation methods.

Bibliography

[1] G. Hudson and C. Underwood (1999), "A SIMPLE BUILDING MODELLING PROCEDURE FOR MATLAB/SIMULINK," in *6th International Conference on Building Performance Simulation*.

[2] J. A. Crabb, N. Murdoch, and J. M. Penman (1987), "A simplified thermal response model," *Build. Serv. Eng. Res. Technol.*, vol. 8, no. 1, pp. 13–19.

[3] "Climate Imperial - California and Weather averages Imperial," *US Climate Data*. [Online]. Available: http://www.usclimatedata.com/climate/imperial/california/united-states/usca0508. [Accessed: 26-May-2014].

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Energy efficiency in Spanish social housing stock. Façade composition and energy demand review (Best Paper SB13 California)

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Abstract:

Characterization of the energy performance in social housing is taken as the point of departure for proposals for construction-related improvements. The improvement in vertical enclosures can contribute to avoid energy poverty, urban vulnerability, and energy dependence while improving indoor comfort.
Though the specific characteristics of the enclosures are difficult to determine for spanish social housing stock, different reports and prior studies are reviewed, and some specific buildings in Madrid were analized, concluding that the potential for improvement in existing buildings is huge taking into account also social and economic aspects.

Keywords: energy demand, social housing, vertical enclosure, U value, existing buildings,

1. INTRODUCTION

Energy efficiency is on political agendas at every scale, from the International Energy Agency down to local governments. Improving energy efficiency constitutes one of the clearly established lines of action in many long-term plans. The paper submitted forms part of a study on the possibility of improving vertical enclosure systems in Spanish **social housing** using innovative products to enhance both the quality of the indoor environment and the energy efficiency of these buildings.

Meeting those aims calls firstly for an accurate diagnosis of housing type, present condition and energy performance. The city of Madrid was taken as the reference starting point for the study for its temperate climate, and because its housing stock distribution is representative of multi-family dwellings nation-wide.

Characterization of the energy demand in social housing is taken as the point of departure for proposals for construction-related improvements, in which the use of **passive systems** can raise the number of hours of indoor comfort per year with no need to resort to active energy systems. Such improvements in passive performance are particularly necessary where the use of active systems is constrained for want of financial resources, i.e., in segments of the population that endure **energy poverty**. Energy **consumption** is found to be low in these buildings due to occupant constraint in the use of environmental control, which translates into less comfort and consequently a lower **quality of life**. The increasing energy price also worsens this situation.

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In addition to energy performance, improvements in vertical enclosures involve the renovation and enhancement of features such as building aesthetics, with the concomitant beneficial impact on the surrounds and in subjective vulnerability perception. Lower energy demands for heating and cooling also have a beneficial impact on **power generation and distribution** infrastructures. Although the upward trend in residential energy consumption has flattened somewhat with the economic crisis, meeting that demand entails enlarging such infrastructures with the concomitant intensification of environmental impact and **energy dependence**.

Lastly, a number of reports have quantified the **job generation potential** of this type of measures, significant taking into account the increase in unemployment in the construction sector in Spain and its effect in social housing neighbourhoods.

2. SHARE OF SOCIAL HOUSING IN THE OVERALL STOCK

A discussion of the milestones and indicators that characterize the existing housing stock in Spain and its energy performance is a necessary first step to study multi-family social housing refurbishment in cities. In trying to define the share of social housing, and taking as starting point the right to housing and ensuring universal access, several definitions were found, ranging from a classical perspective of housing granted within the framework of social policy, to one that focuses on socioeconomic factors, defined as those intended to vulnerable citicens that are financially out of the housing market and therefore not have access to it.

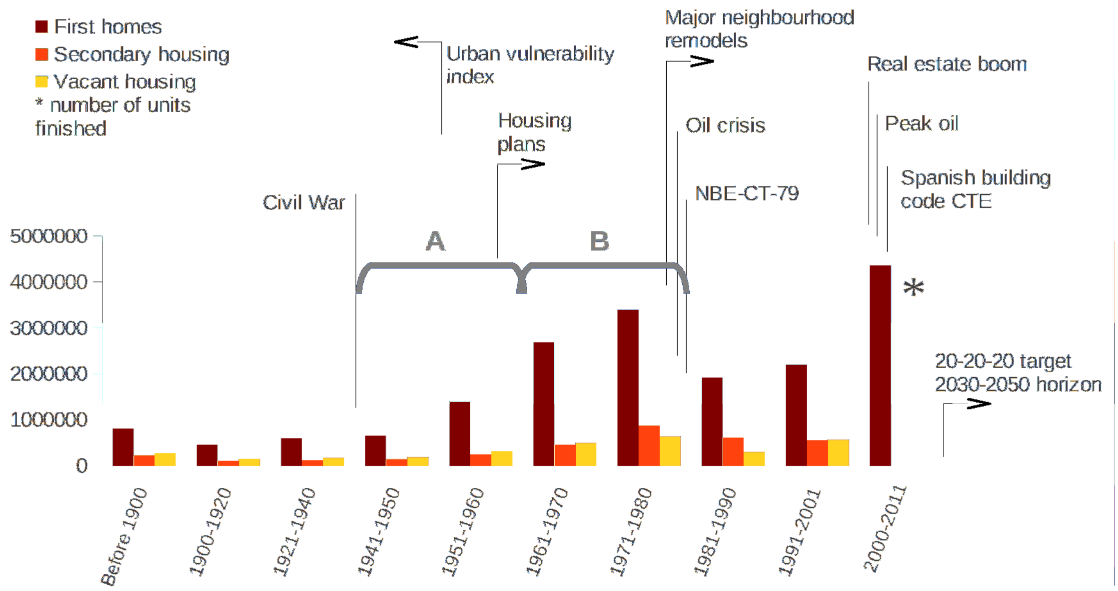

Fig. 1 Number of first and second homes and vacant units in Spain (INE, 2001) and number of newly built homes (Ministry of Internal Development, 2011).

The data in *Fig. 1* characterizes the existing stock: number of first and second homes and vacant units in primarily residential buildings; number of newly built units since 2001. The Civil War is also marked (1936-39), buildings prior to 1951 as an indication of residential vulnerability (Hernandez, 2001); the start-up of the successive housing plans, in particular the

Third National Housing Plan during the dictatorship (1961-1976), with the concomitant neighborhood remodels, conducted in Madrid by the local housing institute (Spanish initials, IVIMA) beginning in the nineteen seventies; the oil crisis in the same period and the introduction of energy criteria in legislation enacted in 1979; the real estate bubble and subsequent economic crisis when it burst in 2006; the publication of Spain's Technical Building Code; and the transposition of recent European energy efficiency-related plans and directives clearly designed to reduce greenhouse gas emissions in the short and long term.

The figure also identifies the two selected periods of this study, A and B (1940-1960; 1961-1979) with obvious differences in terms of number of housing units, whose construction and energy characteristics are described below. Housing needs began to rise in Spain after the country’s Civil War. Mass migration to urban centers and the paucity of resources generated a housing stock heavily impacted by successive plans and actions undertaken during the dictatorship. Beginning in the nineteen seventies, neighborhood remodels driven by grassroots organizations began to raise quality standards, generally in response to the appearance of infra-housing of different types. In Madrid these included “urban villages” consisting essentially of shanties, small shantytown enclaves, ethnic minority (mostly Gypsy) settlements, and districts created around precarious public housing built by the National Housing Institute and the Trade Union Homebuilding Initiative (Casanova, 2008). In 2001 only 67 % of the existing housing units were first homes. At this writing, the housing stock is estimated to include 16.7 million first homes, 4 million second homes, 3.7 million vacant dwellings and an unsold stock, in 2011, of one million units (Silva, 2012).

Region-wide, social housing in the city of Madrid can be divided into districts under criteria of **urban vulnerability** (Hernandez, 2001) refered to a combination of social disadvantages that increase threats and risks affecting people, societies, social groups, or states and weakening the mechanisms to address them. Another conceit addressed in this study is **energy poverty**, defined to be the situation existing in households unable to pay for sufficient energy services to meet their domestic needs or that spend an overly large share of their income on residential energy bills. Further to that definition, 10 % of Spanish households are estimated to be energetically impoverished (Tirado, 2012). The increasing energy prices and the financial crisis that has afflicted the country in recent years has had an enormous impact on society and in particular on the real estate industry, worsening this situation for many households.

Current European policy pursues cost-effective or optimal levels of energy efficiency for new and existing buildings and their elements, defining the necessary improvements in terms of reference models (EC, 2012) This indicator makes sense specially in social housing.

3. THERMAL PERFORMANCE

The factors that determine thermal performance include environs-related questions such as climate, urban surrounds and user behavior. Buildings respond to these conditions depending on their design, construction and systems.

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In light of their social significance, housing units in multi-family buildings have been chosen as a reference, even though their mean consumption, at 7 859 kWh/year (0.028 TJ), is 25 % lower than the national average. Mean consumption in housing located on the part of Spain with a continental climate is 13 141 kWh/year or 0.047 TJ, 27 % higher than the national average. Heating accounts for 55.3% of total consumption in this region, followed by household appliances with 17.6%, DHW with 17.4%, kitchen appliances with 6.5%, lighting with 2.6% and air conditioning with 0.7% (IDAE, 2011).

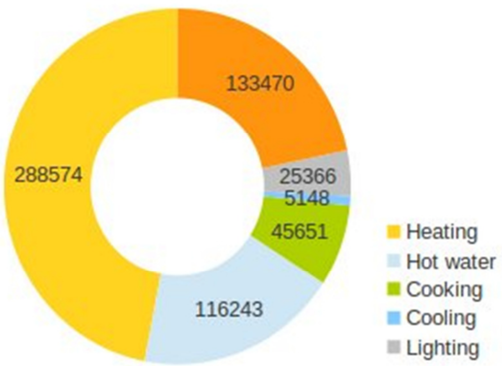

Fig. 2 Housing energy consumption (Spain, TJ) (IDAE,2011).

Uncertainty about the housing sector's contribution to energy demand is high due to the total lack of either energy consumption monitoring in the Spanish building stock or indirect estimates (García, 2011) The stock performance can be characterized, on the one hand, by estimates based on theoretical simulations for the residential sector as a whole or for specific buildings, and on the other, from some admittedly scant real data collected by monitoring thermal behaviour.

One of the aims here was to ascertain the thermal performance of multi-family residential buildings from different reports and prior studies, reviewing: the estimated energy required to heat and cool multi-family buildings erected between 1939 and 1979 and the behavior of opaque vertical enclosures in these buildings.

3.1 Energy demand

The main parameters that determine heating and cooling demands include climate, urban environs (obstruction, wind), building design (compactness, solar radiation), construction elements (percentage of openings) and materials and systems (conductivity, inertia). A wealth of data on heating and cooling demand calculations can be found in the literature. The energy certification scheme for multi-family buildings in Madrid (table 1) provides reference data for new buildings (IDAE, 2009) and for existing buildings (IDAE, 2011)

In a prior study, the present authors reported their heating and cooling demand findings for a variety of façade types exposed to different conditions. Demand was logically small compared to the values for older buildings, because transmittance in these enclosures was lower (0.3, 0.6 and 0.9 W/m2·K, fluctuating with the indoor mass).

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The final essential factor in such studies is **user behavior.** In social housing especially, information on household use profiles is the key to characterizing energy consumption and user comfort, in light of the significant differences from one profile to another. Standardized values based on seasonal use estimates are applied in simulations and legislative calculations.

Broken down by the respondent's occupational status, while 74 % of the employed and 67 % of people not in the workforce had heating, only 53 % of the dwellings occupied by the unemployed were so equipped (last data for Spain is 26% population unemployed, 2012). The respective percentages for air conditioning are 40, 29 and 31 %. Income levels are also observed to be associated with behavioral differences (INE, 2008).

	Heating demand (kWh/m^2K)	Cooling demand (kWh/m^2K)
Reference (new)	**43,2**	**10,8**
A-B	9,4	3,96
B-C	21,8	6,48
C-D	39,6	10,08
D-E	66,3	15,48
Reference (existing)	**121,2**	**19,1**
E-F	119	18,2
F-G	130	22,6

Table 1. Heating and cooling demand in energy certification scale for multi-family buildings in Madrid

3.2 Opaque vertical enclosures

The establishment of increasingly demanding energy quality standards has identified the need for some manner of action in virtually the entire stock of existing residential buildings. A study conducted specifically in the city of Madrid (Luxan, 2010) found that the effectiveness of such action is highest in buildings where energy performance is lowest. That study made specific reference to buildings erected prior to the enactment of building code NBE-CT-79 as well as to the important energy savings role of enclosures, outer walls especially, which in some cases may provide over 70 % of the total savings possible.

The specific characteristics of the existing enclosures are difficult to determine. In Fig.3 and Fig 4 different types of enclosures have been represented by assuming transmittance, U (W/m2·K), to be the property with the greatest effect on building in use energy performance.

The reference data for the various enclosures are widely scattered. In most of the enclosures to be rehabilitated, thermal transmittance lies between 1.2 W/m^2K (minimum required in the 1979 code) and 3.0 $W/m^2 \cdot K$, and always above the building code requirements for Madrid (CTE 0,66 W/m^2K) Thermal storage in this enclosures has also been addressed in previous papers, concluding that there is also a huge potential taking adavantage on existing heavy enclosures.

The improvements proposed in the review papers envisage values very close to the present code requirements and all of the cases reviewed fall far short of complying with the 0.15 $W/m^2 \cdot K$ Passivehaus recommendation (Diaz, 2012), necessary for achieving net zero objectives.

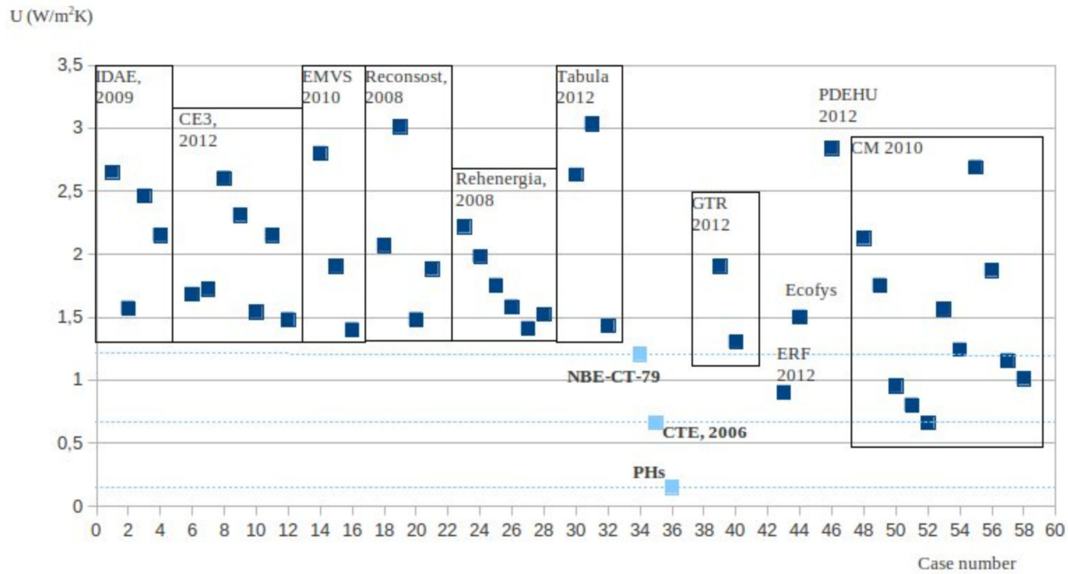

Fig. 3: U value for different standard, reports and studies in existing buildings (1939-1979). (NBE-CT-79, CTE, 2006, Passivehaus PHs) (IDAE 2009,2011 CE3tool 2012 Luxan, 2010 Martin, 2008 -2008, Ortega 2011 GTR, 2012 Capdevila 2012 Ecofys, CENER, 2012 CM 2010)

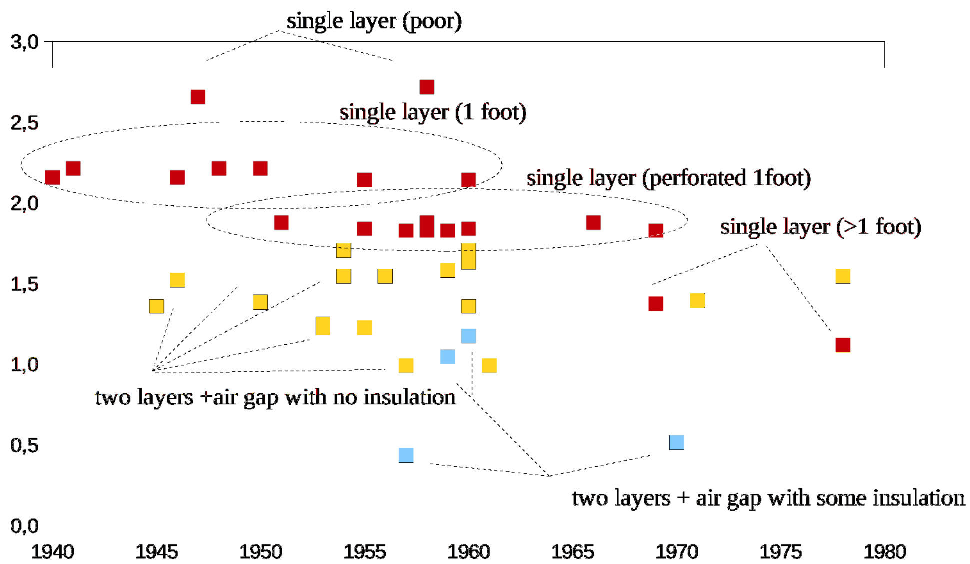

Fig. 4 Calculated U value for 53 buildings in Madrid.for different construction years from 1940 to1980 (autor reference, 2014)

4. DISCUSSION AND CONCLUSIONS

Bearing in mind the relevance of the construction and housing industries for medium- and long-term emissions reduction, ambitious strategies and objectives should be envisioned to guarantee the sustainability of the housing stock and to reduce energy vulnerability. Certain issues along these lines have been addressed in earlier papers, including the importance of diversity in the type of actions pursued, with adapted and adaptable solutions for renovation cycles, and life cycle analysis based on comprehensive and detailed case-by-case reviews.

The conclusion to be drawn from this initial analysis is that the reference data are widely scattered, both as regards heating and cooling demand and the type of reference enclosure used in the calculations. Despite this dispersion, the general consensus is that the potential for improvement is huge. Most of the papers reviewed propose general building overhauls to attain substantial long-term improvements in a short period of time, with significant reductions in energy demand and consumption. These improvements can also be achieved gradually, with individual solutions at element scale.

Energy demand for environmental control has been used as a reference for determining a building's thermal quality. Such demand is determined from standardized use and comfort parameters, however, which should be reviewed to ascertain whether they are in keeping with the local social and cultural context and needs to be compared to actual in-service values.

At a time when major rehabilitation operations are being put forward, the lessons learnt from the errors and experience accumulated in large Spanish cities during past neighborhood remodels and similar types of action provide very helpful background information. A number of factors characterize each period of the residential sector history: the appearance of environmental concerns in the nineteen seventies, essentially ignored by the industry until the advent of European initiatives, or the housing construction boom over the last 10 years.

A further source of useful information lies in the rehabilitation proposals under consideration in other net energy importer cities in Europe, and in general in other cities with climates similar to Spain's that pursue residential energy savings and efficiency.

5. AKNOWLEDGEMENTS

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6. REFERENCES

Alonso, C. Oteiza, I. 2013. *Energy efficiency in Spanish social housing stock. Review of façade composition and energy demand recent literature.* BESS SB13. Building Enclosure Sustainability Symposium- Sustainable Buildings Conference. Pomona, California.

Alonso, C. González, M. Oteiza, I. Monjo, J. 2014 Hacia *una rehabilitación de la vivienda social. transmitancia e inercia térmica de la envolvente vertical de edificios singulares en Madrid 1939-1979.* Rehabend. Congreso latinoamericano sobre patología de la construcción, tecnología de la rehabilitación y gestión del patrimonio. Universidad de Cantabria.

Capdevila et al 2012. *Eficiencia energética en la rehabilitación de edificios*. Fundacion Gas Natural.

CENER 2012. *Programa de diagnóstico energético del habitat urbano.* PDEHU.

Casanova Gómez, C. 2008. *De las políticas urbanas a la lucha contra la exclusión social 100 años de intervención pública en la vivienda y la ciudad. La vivienda de realojo.* Sambricio, C. & Lampreave., R. S. (Eds.) AVS, 2008, 191-214.

CE3 Tool 2012. http://www.minetur.gob.es/energia/ viewed January 2013

CM, Comunidad de Madrid. 2010. *Guía de rehabilitación energética de edificios de viviendas.* <www.madrid.org> viewed January 2013

Cuchi, A. et al 2012. Informe GTR 2012. Una visión país para el sector de la edificación en España.

Diaz, N 2011. *La envolvente opaca y el aislamiento: Minimizar pérdidas. Guía del estándar Passivehaus.* Fundación de la energía de la Comunidad de Madrid.

EC, European Comision. 2012 REGLAMENTO DELEGADO (UE) No 244/2012

Garcia Casals, X. 2011. Un sistema energético basado en inteligencia, eficiencia y renovables 100% Greenpeace

Hernandez, A. et al. 2001. *Análisis urbanístico de barrios vulnerables. Observatorio de la Vulnerabilidad Urbana.* Ministerio de Fomento. <http://atlasvulnerabilidadurbana.vivienda.es> viewed January 2013

IDAE. 2011 *Análisis del consumo energético del sector residencial en España.* SECH-SPAHOUSEC project. < http://www.idae.es/> viewed January 2013

IDAE 2011. *Escala de calificación energética. Edificios existentes*

IDAE. 2009. *Escala de calificación energética. Edificios de nueva construcción.*

INE, National Statistics Institute. 2001. *Census on population and housing*, www.ine.es viewed January 2013

Luxán, M. et al. 2010 *Metodología de evaluación para el programa de ayudas a las actuaciones de rehabilitación para la mejora de la sostenibilidad y eficiencia energética de las edificaciones.* Proceedings SB10Mad Sustainable building conference. Madrid, April 28-30

Martin et al 2008. *Viabilidad técnico- económica de soluciones bioclimáticas en edificios existentes.* From OSE <http://www.sostenibilidad-es.org> viewed January 2013

Ministry of Internal Development. 2011. *Habitability permits issued.*

Ortega, L Serrano, B. 2011. *Use of Building Typologies for Energy Performance Assessment of National Building Stock. Existent Experiences in Spain.* TABULA Project. <http://www.building-typology.eu> viewed January 2013

Silva, R. 2012 *La eficiencia ambiental y energética en la rehabilitación de edificios*" Proceedings Gas Natural. Madrid, November 7

Tirado, S.; López, S. & Martín, P. 2012. *Pobreza energética en España. Potencial de generación de empleo derivado de la rehabilitación energética de viviendas*. Asociación de ciencias ambientales, ACA.

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Double skin façade for naturally ventilated office buildings in Brazil

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Abstract: *The double skin façade (DSF) is a developing design option for buildings that can lead to improvements in the indoor thermal comfort. Most of the studies about the DSF have been conducted using air-conditioned building models, although applied in naturally ventilated buildings. This study investigates if satisfactory thermal acceptance can be achieved in naturally ventilated buildings with DSF in Brazil. It presents the range of natural ventilation performance that can be achieved by the DSF, based on a generic building model, in response to the impact of solar radiation on the façade. Building thermal and computational fluid dynamic simulations were systematically performed to establish air temperature and air movement within the occupied spaces in the model. Periods of thermal acceptance, examined using the adaptive comfort criteria of different regional and seasonal variations in Brazil are presented. The study demonstrated that there is a potential to adopt DSF in some regions of Brazil.*

Double skin façade, Brazilian climate, Thermal comfort, Passive solar design, Natural ventilation

Introduction

A double skin facade (DSF) consists of a normal façade, an air cavity and an additional external skin usually made of glass. The main advantage is the potential to reduce the heating and cooling loads while having transparent façade of modern buildings. However, its implementation is accompanied by significant challenges in terms of adaptability to climatic conditions of different geographical areas [1] [2].

The temperature difference between the outside air and cavity air created by the solar intensity reaching the DSF has been identified as one of the most important elements in generating ventilation for the indoor space. It is the main natural stimuli of the thermal and airflow behaviour of the DSF as studied by Kim et al. [3] and Gratia and De Herde [4]. The phenomenon of thermal chimney on the DSF occurs due to the density difference between the warmer air inside the cavity and the cooler outside air. The air inside the cavity is warmed up by the solar radiation and exhausted to outside from the top of the cavity. In naturally ventilated building fresh air is often drawn from windows on the opposite side of the DSF, passes through the occupant space and is then discharged into the cavity of the DSF [5] [6] (Figure 9). Thus, the effective use of the DSF can enhance natural ventilation for cooling purposes by stack effect driven by the heat from the sun.

Analyses of the impact of different radiation levels reaching the DSF have been performed by Stec and Paassen [7] and Gratia and De Herde [4] who assessed the cavity behaviour of air

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conditioned building models. The results suggested under sunny days the temperatures in the cavity can exceed the surrounding temperature by around 6°C. Despite the studies being conducted using air conditioned models, the possibility of using the technology as a mean to introduce natural ventilation to buildings has been suggested [5], [8], [9].

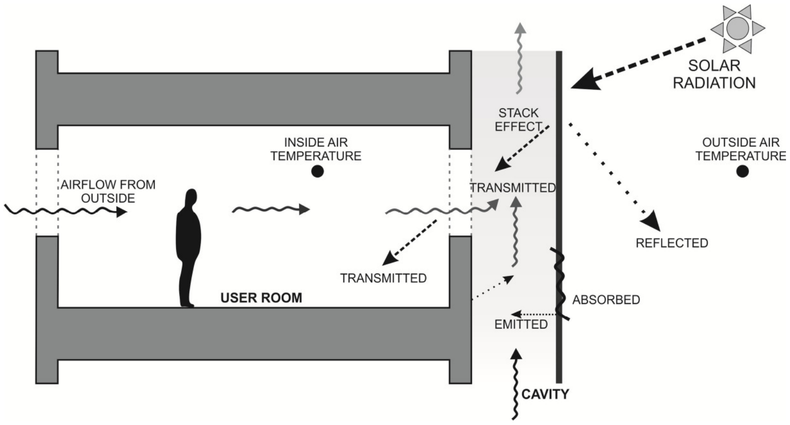

Figure 9- DSF and the adjacent office floor cross-section with the heat transfer and airflow mechanisms.

However, to date there is hardly any investigation to assess the DSF applicability in naturally ventilated buildings in particular in hot climates. With the increasing use of glazed façade and need for energy efficient buildings in Brazil, this study set out to investigate if satisfactory thermal acceptance can be achieved in naturally ventilated buildings with DSF in such climate. This study investigates the range of ventilation that can be achieved by the DSF in a generic building model in response to the impact of solar radiation on the facade. The assessment demonstrates the worst case scenarios, representing locations with low or zero wind speeds.

Methodology

The study was divided into three stages. The first stage identified the Brazilian climatic zones of which the natural ventilation was considered by the Brazilian code as an appropriate strategy to improve indoor thermal comfort and the generic model used on the simulations was developed. Secondly, a sensitivity analysis of 24 cases scenarios with selected outside temperatures and heat flux incidences on the façade were performed. These provided correlations of airflows and mean air speeds in the user rooms according to the differences of temperatures achieved in the DSF cavity and the outside air. Finally, the air speed driven by the DSF and the air temperature in the user room were established to verify the thermal acceptance of the model in different bioclimatic zones in Brazil.

Climate characterization

Brazil comprises of a wide range of climatic conditions with the largest portion of the country considered as tropical [10]. The climate classification proposed by the national standard [11] divides the territory into eight relatively homogeneous climate areas (Figure 10a), indicating a suitability set of passive strategies for each climatic zone within which natural ventilation is a viable option to meet the thermal comfort requirements. The cities selected for this study are the main cities in each bioclimatic zone. The percentages of the year in which the natural

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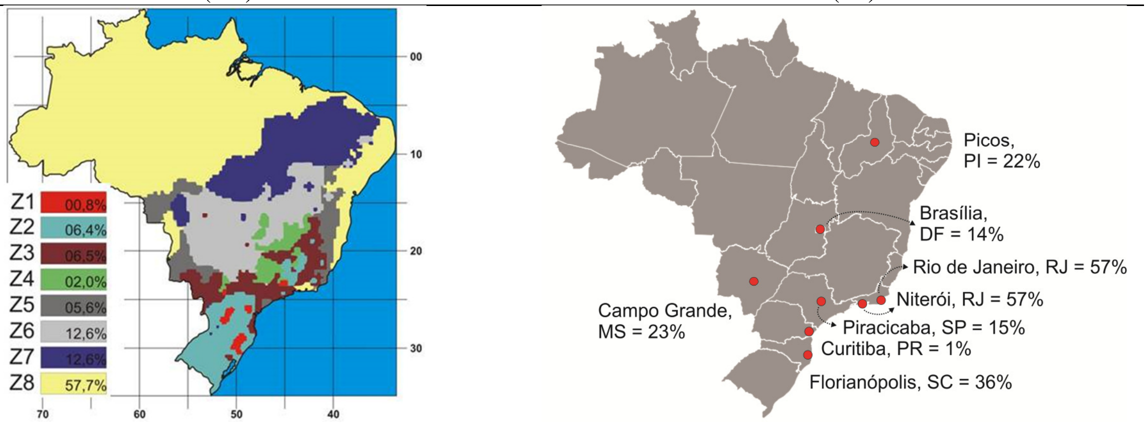
ventilation is expected to meet the required indoor thermal comfort for these zones are shown in Table 3.

Table 3 – Cities selected according to the bioclimatic zone.

Clim.Zone	City	Expected natural ventilation (year)	Clim. Zone	City	Expected natural ventilation (year)
1	Curitiba (PR)	1%	**5**	Niteroi (RJ)	30%
2	Piracicaba (SP)	15%	**6**	Campo Grande (MS)	23%
3	Florianopolis (SC)	36%	**7**	Picos (PI)	22%
4	Brasília (DF)	14%	**8**	Rio de Janeiro (RJ)	57%



(a) *(b)*

Figure 10: (a) Incidence of the eight bioclimatic zones in Brazil. Source: ABNT [11].(b) Locality of the cities selected in this study.

Model description

The generic simulation model used for this study is a rectangular shape (30m x 12m) building with 10 floors (Figure 11). The building format was selected to maximize the effect of natural ventilation produced by the DSF, which is related to the degree of exposure to solar radiation and flow resistance. The DSF was modelled as the multi-storey type in which the cavity is opened vertically and horizontally covering the entire face of the building. The properties of the materials used in the envelope and the openings profiles are specified in Table 4.

Table 4 – Characteristics of the model

Building envelope

Roof (super insulated flat roof): U value = 0.18 W/m^{2}K
Ground floor (super insulated roof): U value = 0.28 W/m^{2}K
Opaque part of façade: U value = 1.89 W/m^{2}K; Thickness = 0.17m
Windows (WWR=50%): low-e double glazing: U value = 1.94 W/m^{2}K; visible light normal transmittance = 0.76.

Double skin

Clear single glass: U value = 5.04 W/m^{2}K, shading factor = 0.87
Width of the cavity: 50cm
H (DSF) = H (building)

Use of the building (internal heat gains) = 9.54 kW in each level

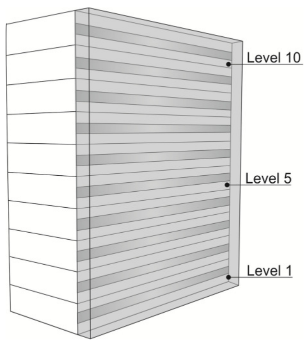


Figure 11 – Building model used on the simulations

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Simulations and the mathematical correlations

Two software were used iteratively in this project: FLOVENT (version 9.3) and IESVE (version 2013). The first is a Computational Fluid Dynamics (CFD) tool designed to simulate the airflow and heat transfer within rooms or buildings. The second is a dynamic building energy simulation software (BES) used to investigate the thermal performance of the building.

Twenty four CFD scenarios were studied on the proposed building model. They consist of four outside temperatures combined with 6 solar incidences varying from 100 W/m^2 to 600W/m^2 as shown in Figure 12. These represent the typical range of climatic parameters. The additional wind induced airflow has been excluded, such that the airflow is only driven by the thermal buoyancy force of the DSF. The simulations calculated the airflows for each level enabling the correlations of the airflow in the cavity and within the occupied spaces according to their dynamic thermal interactions. The results from CFD simulations were imported to the dynamic building thermal simulation software IESVE in which detailed indoor thermal and comfort were studied using hourly weather data generated with reference to the Brazilian bioclimatic zones.

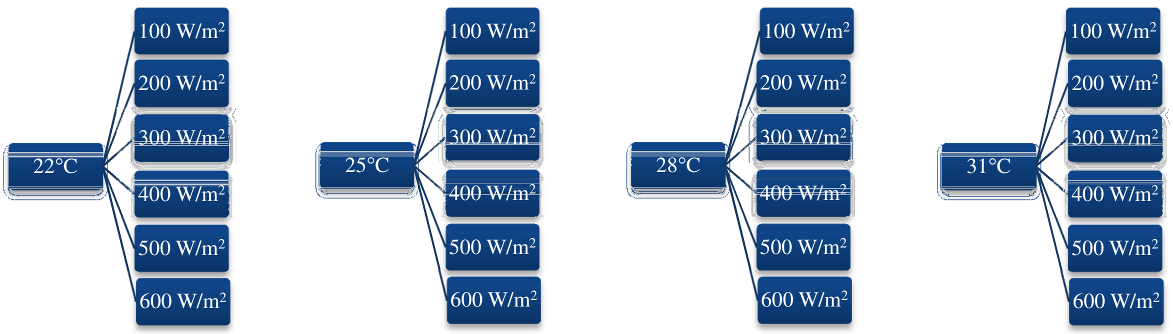

Figure 12 – 24 case scenarios used to perform the sensitivity analysis.

Using mathematical correlations, the airflow and the mean air speed were calculated for the bioclimatic zones where natural ventilation is considered suitable. The thermal comfort was then evaluated by using the standard EN 15251 [12], which adopts the adaptive approach model to naturally ventilated buildings. The results present the range of acceptable room temperature according to the outdoor temperature, the indoor air speed and the indoor operative temperature.

Influence of solar radiation on natural ventilation

The analysis of the effect of the heat flux intensity on the DSF showed that the increase of temperature in the cavity was directly related to the amount of heat gain by the façade. However, the cases under the same heat flux intensity had the similar increase of the cavity temperatures despite changes in the outside air temperatures. Thus, the effect of the heat transmission by conduction through the external air and the façade was very small when compared to the radiation influence.

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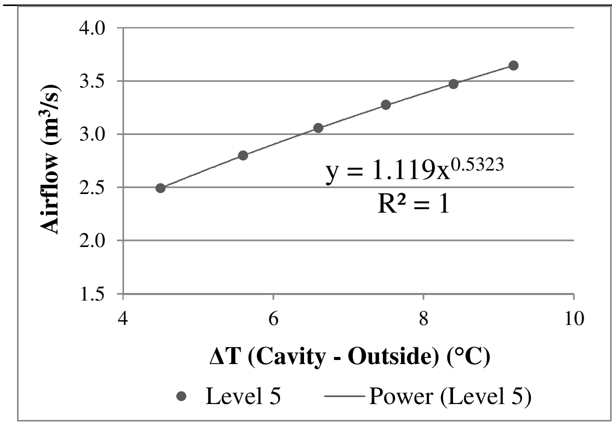
The difference of temperature between the cavity and the outside air (*ΔT*), the airflow in the occupied area and air speed in the cavity due to solar heat flux are illustrated using the results of level 5 as shown in Table 5. It shows the difference of the temperature between the cavity and the exterior air reached 6.6°C, when the heat flux transmitted into the façade was 300W/m^2. The corresponding mean air speed in the cavity achieved was 1.73m/s. The maximum indoor air speed varied from 0.72 to 0.92m/s, but the mean air speed on the same level varied from 0.11 to 0.14m/s.

Table 5_ Influence of solar intensity on the DSF performance

Heat flux intensity (W/m^2)	Difference of temperature ΔT (cavity – outside) (°C)	Airflow cavity (m^3/s)	ACH Cavity	Airflow level 5 (m^3/s)	ACH Level 5	Mean air speed (m/s) Level 5	Max air speed (m/s) Level 5
100	4.5	19.5	134	2.5	7	0.11	0.72
200	5.6	22.2	152	2.8	8	0.12	0.75
300	6.6	24.3	167	3.1	9	0.13	0.80
400	7.5	26.0	178	3.3	9	0.13	0.84
500	8.4	27.6	189	3.5	10	0.14	0.88
600	9.2	29.0	199	3.6	10	0.14	0.92

Figure 13 shows the trend line that expresses the correlation for airflows according to the *ΔT* on level 5. These results provided a summary of the quantitative representation of the potential air flow/speed that can be achieved by the use of DSF. The equations and the coefficients of determination for all other levels are presented.



Level	Correlation	Coefficient of determination
1	$y = 2.3123x^{0.5036}$	$R^2 = 0.9889$
2	$y = 1.8423x^{0.4874}$	$R^2 = 0.9959$
3	$y = 1.4511x^{0.504}$	$R^2 = 0.9993$
4	$y = 1.1912x^{0.5317}$	$R^2 = 0.9998$
5	$y = 1.119x^{0.5323}$	$R^2 = 1$
6	$y = 0.9963x^{0.5381}$	$R^2 = 0.9999$
7	$y = 0.9115x^{0.5384}$	$R^2 = 1$
8	$y = 0.8451x^{0.5341}$	$R^2 = 0.9999$
9	$y = 0.7844x^{0.6055}$	$R^2 = 0.9999$
10	$y = 3.0198\ x^{0.4075}$	$R^2 = 0.9972$

Figure 13 –Airflows on different levels as function of the differences of temperatures between the cavity and the outdoor air

Figure 14a presents the mean air speeds on level 5 over the year in climate zone 8 (Rio de Janeiro city) according to the seasons. It can be seen that the greatest air speeds occur during the winter and autumn seasons, while in the summer and spring, these values are slightly lower. The lower sun angles during the cold months result in higher solar intensities reaching the façade. Despite the fact that the mean air speed values are not considerable high, it is important to mention that highest air velocities occurs at about 1.60m from the floor, where the users usually spend their time in office buildings, as shown in Figure 14b.

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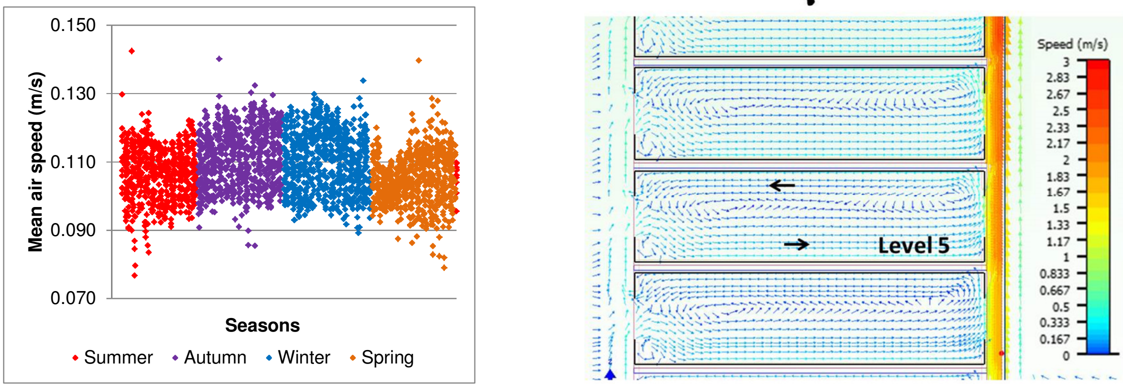
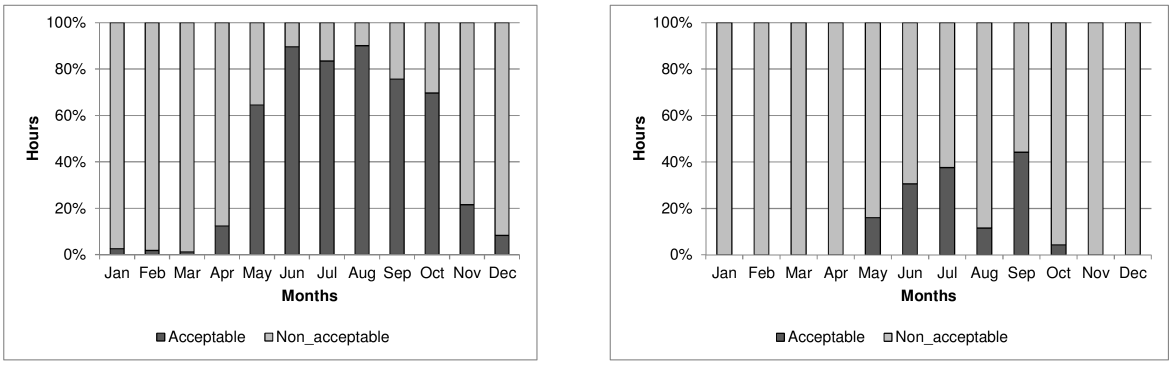


(a) (b)

Figure 14 – (a) Mean air speed in level 5 according to the seasons of zone 8. (b) Vectors of air speed (case scenario: outside temperature = 25°C and heat flux = 300W/m^2

Figure 15 presents the periods of the year in which the air speed established to level 5 is sufficient to maintain thermal comfort according to the external air temperatures in climatic zones 3 and 8.



Zone 3 –Florianopolis (SC) *Zone 8 – Rio de Janeiro (RJ)*

Figure 15 – Hourly thermal acceptance in the building with DSF in zones 3 and 8.

Table 6 – Acceptance level in the bioclimatic zones most likely to be cooled by natural ventilation.

Zone 3	Zone 5	Zone 6	Zone 8
Accepted: 43%	Accepted: 41%	Accepted: 12%	Accepted: 12%
Not accepted: 57%	Not accepted: 59%	Not accepted: 88%	Not accepted: 88%

In climatic zones 3 and 5 (Table 6) the DSF building is able to promote adequate natural ventilation to the user rooms in more than 40% of the year. In zone 3, the highest acceptance levels were achieved from May to October, which can be explained by the lower outside temperatures during the coldest months. On the other hand, in zone 5, the DSF model appears as a satisfactory passive strategy from June to December, covering also the spring season.

Lowest acceptance levels occurred in the cities located in zones 6 and 8, which can be due to the high outside air temperatures associated with the low air speeds created by the DSF buoyance effect. In 90% of the daily hours (8 a.m. to 6 p.m.), Rio de Janeiro (zone 8) presents the outside temperature equal or less than 30°C. Thus, the application of natural ventilation is a potential passive strategy to maintain the thermal comfort in this area. The challenge is still to find out if it is possible to achieve adequate room air speed through the DSF application.

Conclusions

Natural ventilation is a low impact passive strategy for maintaining thermal comfort inside buildings and the double skin façade (DSF) is a potential design option to stimulate the air movement. This study investigates if satisfactory thermal acceptance can be achieved in naturally ventilated buildings with DSF in Brazil. The results show that airflows in the cavity and in the user room driven by the DSF are directly related to the solar radiation falling on the façade, while the effect of the heat conduction through the façade has insignificant effect.

The air speeds observed in the model promoted a relatively high thermal acceptance level (around 40%) in buildings in the south and southeast regions, which have the lowest and mildest temperatures of the country. On the other hand, for the warmer areas in the southwest and centre-west, the DSF can be able to promote sufficient ventilation during the winter and spring seasons, while for the hotter days, the ventilation produced is inadequate. Lowest acceptance levels were observed in the centre-west, north and coastal regions of the country due to the high outside temperatures. The acceptance level in Campo Grande (zone 6) and Rio de Janeiro (zone 8) was around 12%.

This research has demonstrated that DSF is a potential technology, as part of a mixed-mode ventilation strategy, to reduce the annual energy consumption in certain regions of Brazil during some periods of the year. With the increasing use of glazed façade in office buildings in Brazil, there is a clear necessity to evaluate in details the applicability of DSF and to develop the guideline and performance data required by the design professionals.

Acknowledgment

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References

[1] J. Darkwa, Y. Li, D.H.C. Chow. Heat transfer and air movement behaviour in a double-skin façade. Sustainable Cities and Society 2014; 10:130-139.

[2] G. Quesada, D. Rousse, Y. Dutil, M. Badache, S. Hallé. A comprehensive review of solar facades. Transparent and translucent solar facades. Renewable and Sustainable Energy Reviews 2012; 16:2643-2651.

[3] Y.-M. Kim, S.-Y. Kim, S.-W. Shin, J.-Y. Sohn. Contribution of natural ventilation in a double skin envelope to heating load reduction in winter. Building and Environment 2009; 44:2236-2244.

[4] E. Gratia, A. De Herde. Greenhouse effect in double-skin facade. Energy and Buildings 2007; 39:199-211.

[5] W. Ding, Y. Hasemi, T. Yamada. Natural ventilation performance of a double-skin façade with a solar chimney. Energy and Buildings 2005; 37:411-418.

[6] H. Radhi, S. Sharples, F. Fikiry. Will multi-facade systems reduce cooling energy in fully glazed buildings? A scoping study of UAE buildings. Energy and Buildings 2013; 56:179-188.

[7] W. Stec, D.v. Paassen, Sensitivity of the double skin facade on the outdoor conditions, Beijing, 2005.

[8] N. Mingotti, T. Chenvidyakarn, A.W. Woods. The fluid mechanics of the natural ventilation of a narrow-cavity double-skin facade. Building and Environment 2011; 46:807-823.

[9] S.A. Barbosa, T.M.d.S. Tibúrcio, J.C. Carlo, Í.B.B. Guimarães. Método de utilização do programa Energyplus para verificação de desempenho térmico de ambientes com fachadas duplas. Revista ambiente Construido 2013; 13. (In portuguese)

[10] M. Leão, V. Huckemann, É.B. Leão, M.N. Fisch, E. Kuchen. Energy efficiency of double skin façades: an approach to Brazilian climates. Bauphysik 2009; 31:8.

[11] ABNT, Desempenho térmico de edificações Parte 3: Zoneamento bioclimático brasileiro e diretrizes construtivas para habitações unifamiliares de interesse social, Associação Brasileira de Normas Técnicas, 2003, 23. (In portuguese)

[12] CEN, Indoor environmental input parameters for design and assessment of energy performance of buildings-addressing indoor air quality, thermal environment, lighting and acoustics, 2007.

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Session 13:

Which are the bottlenecks in the sustainable urban regeneration process?

Chairperson:

de Santiago, Eduardo

Consejero Técnico. Subdirección General de Urbanismo. Subdirección General de Urbanismo. Ministerio de Fomento. Gob. España

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Rallying to Sustainability of Existing Public Housing Estates

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Abstract: *The Hong Kong Housing Authority (HKHA) is the major government institution in Hong Kong for public housing with a stock of 740,000 public rental housing (PRH) units accommodating over two million people. To sustain the aging PRH estates while coping with the changing needs of the community over time, the HKHA has established a holistic strategy rallying to sustainability through three major maintenance and improvement programmes: the Total Maintenance Scheme (TMS), the Comprehensive Structural Investigation Programme (CSIP) and the Estate Improvement Programme (EIP). Under this holistic strategy, the aged estates are well maintained and rejuvenated through proactive repairs and upgrades of facilities addressing tenants' key concerns and needs. As the community support is crucial in achieving true sustainability, the HKHA, through a series of education programmes, promotional campaigns and incentive schemes, is constantly driving fundamental changes in tenants' attitudes and behaviours towards a more sustainable living style.*

Hong Kong Housing Authority, Public Rental Housing, TMS, CSIP, EIP, Sustainability

1. Introduction

For the past decade, a high level of research interest in sustainable buildings has spawned notable environmental advances in design philosophy, construction methodology, and energy efficiency. Many of the advances have been put into practice today by the building industry resulting in greener buildings with lower carbon footprints and enhanced sustainability. While the Hong Kong Housing Authority (HKHA), which is the statutory body that plans, builds, manages, and maintains different types of public housing in Hong Kong, is at the forefront of adopting various green technologies in new construction, true sustainability cannot be achieved without emphasis on the life cycle of existing public housing estates. To uphold the quality of 740,000 public rental housing (PRH) units in a sustainable manner, the HKHA has developed and implemented a holistic maintenance and improvement (M&I) strategy that includes the Total Maintenance Scheme (TMS), the Comprehensive Structural Investigation Programme (CSIP) and the Estate Improvement Programme (EIP). These key initiatives have proved to be effective in extending the service life of existing PRH estates in a sustainable manner. Yet, with many of the sustainable issues going beyond direct control of the HKHA, the holistic M&I strategy can only be considered as half of the solution to the challenge of achieving true sustainability. The other half of the solution lies in the need of

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paradigm shift in people's attitudes and behaviours. To facilitate the necessary changes for a sustainable future, education programmes and promotional campaigns are launched to inspire tenants to adopt a sustainable living style. With two million people living in PRH estates in Hong Kong, every action taken by the HKHA has a far-reaching effect on shaping the city's landscape in sustainability.

2. Holistic M&I Strategy for Sustainability

Sustainability is the ability to meet today's needs without compromising those of subsequent generations. With the heart of providing quality housing to low-income families in a sustainable manner, the HKHA adopts a holistic M&I strategy for its existing PRH estates, which satisfies the three broad principles (Figure 1) of sustainability as follows:

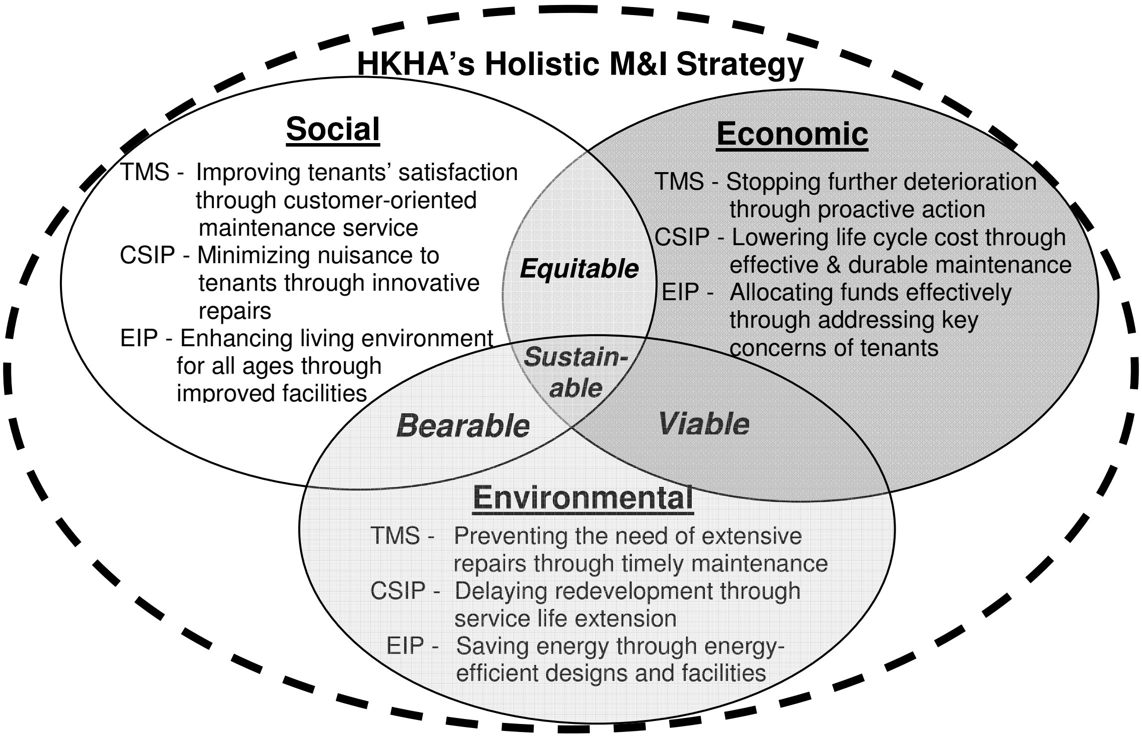

Figure 1: Holistic M&I Strategy for PRH Estates

2.1. Total Maintenance Scheme (TMS)

In 2006, the HKHA launched the TMS, which is a comprehensive, proactive and customer-oriented programme for tenants in a bid to prevent minor repair issues from escalating into major problems. The TMS adopts a three-pronged approach in the delivery of maintenance services in five-year cycles, namely, (i) proactive identification of maintenance problems, (ii) prompt response to tenants' requests for repairs and (iii) enhanced publicity and education to tenants. Rather than reacting to complaints or requests for repairs, in-flat inspection ambassadors, who are trained under the TMS, visit individual households and carry out in-flat condition surveys. With a computerized system developed to support the TMS, inspection findings are recorded on personal digital assistants (PDAs). On-the-spot repairs are carried out for minor defects while works orders are issued with PDAs for prompt rectification of more complex problems. To strengthen communication with tenants, a maintenance hotline supported by a call centre has been set up to handle calls concerning inspection appointments, complaints and enquiries. Regular reports are generated by the computerized system to facilitate monitoring of appointments and repair services. With the computerized system storing inspection survey results and repair records, a comprehensive database has been developed facilitating traceability and in-depth analysis for review of future maintenance strategy.

Making good use of the in-flat inspection opportunity, TMS ambassadors also educate tenants on the proper use and maintenance of the fittings and facilities provided in their flats. To cultivate a customer-oriented service culture, seminars and workshops for experience sharing to maintenance contractors are arranged. Regular meetings are also held with the Estate Management Advisory Committees (EMAC), District Council members and tenants to report work progress and collect feedback. To promote awareness and values of the TMS, a Maintenance Education Centre and various Mobile Maintenance Education Booths are set up for tenants with display boards, videos corners and samples of building components. Promotional videos on proper home maintenance featuring celebrity icons are also broadcast at prominent estate locations.

The TMS is a successful maintenance strategy that addresses environmental, economic, and social aspects of sustainability. Environmentally, there are benefits in terms of a longer service life while minimizing major repairs. Economically, life-cycle repair cost can be reduced by proactively identifying and eliminating minor problems from escalating into major ones. Socially, with timely rectification of defects, tenants can enjoy a better living environment, which has been proven by a tenant satisfaction rate of over 80% since the launch of the TMS.

2.2. Comprehensive Structural Investigation Programme (CSIP)

Launched in 2005, the CSIP is implemented for estates approaching 40 years of age and at a 15-year interval afterwards. The CSIP systematically and thoroughly probes into structural condition of aged PRH buildings and determines whether they are structurally safe and economically viable to maintain. Based on the Comprehensive Structural Investigation (CSI) results, tailor-designed repair solutions are established to extend the service life of aged buildings for at least 15 years. The six major steps for a typical CSI are described below:

i) Desktop Study

A desktop study for a new CSI involves the study of records including repair history, record drawings, design calculations, past structural appraisals, and previous improvement/

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strengthening records. Elements that previously required substantial or repeated repairs are one of the main focus areas in the new investigation.

ii) Visual Survey

A visual survey is conducted to cover all common and external areas. However, excessive inspections of occupied flats can be a nuisance to some tenants. As a result, a representative sampling approach (e.g. a 5% inspection rate for occupied flats) is necessary to balance inspection accuracy with inspection disturbance. Where the level of deterioration varies significantly due to differences in workmanship, usage and performance, a higher inspection rate is used to gain a deeper insight into the deterioration extent and severity. Repair records are retrieved and tenants are also interviewed to obtain a better picture on the history of defects and repairs. Besides documenting all visible defects in structural elements, a visual survey is to identify symptoms and clues which characterize the underlying structural deterioration processes.

iii) Testing

Based on the information gathered from the desktop study and visual survey, a test programme is devised to diagnose the in-depth conditions of the structural elements and confirm the root causes of defects. Destructive tests include rebar corrosion measurements, concrete core compression tests, carbonation depth measurements and chloride content analysis. To minimize disturbance to tenants, destructive tests are mainly conducted in common areas and vacant flats. On the other hand, non-destructive tests are carried out in common areas, vacant flats, and occupied flats as well. These tests include concrete moisture content measurements to quantify the extent of water seepage, concrete void detections to locate delamination and spalling, half-cell potential tests to assess corrosion risks, and corrosion current surveys to understand reinforcement corrosion rates.

iv) Building Service Life Assessment

Adopting the concept of a “reversible limit state” as defined in EN 1990:2002 [1], a structural defect is considered to be an acceptable defect when it can be repaired economically and “reversed” if appropriate action is taken. On the other hand, a building with structural defects that cannot be economically restored or repaired is considered to be beyond the ‘reversible limit state’ and is at the end of its service life. With sufficient data collected from a well devised testing programme, a service life assessment can be carried out to facilitate the development of a sustainable repair scheme in extending the service life of an aged building as follows:

- Appraise the residual capacity of various structural elements and assess structural stability based on the current structural conditions;
- Evaluate the severity, extent and nature of deteriorations. Establish the causes and mechanisms of the deteriorations and assess factors which could have significant effects on the degradation process such as concrete covers, screeding thicknesses and material strengths;

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- Estimate future deterioration rates for various groups of structural elements based on condition survey data, existing chloride contents, carbonation depths, and current corrosion rates. Particular attention should be given to the effects of various repair schemes on future deterioration rates; and
- Assess structural stability and appraise the residual capacity of structural elements with proper maintenance.

v) Building Service Life Extension

Structural deterioration is a complicated process that can be attributed to a variety of interactive mechanisms. Understanding the causes and delivering the right solutions are the keys to service life extension of aged buildings. With the HKHA placing more emphasis on service-oriented culture, the success of a repair work is now also heavily weighed against tenants' satisfaction. Tenants, as the receivers of service, may not understand the long term quality or cost of a repair. Rather, they care more about how a repair is handled, how disturbing (e.g. dust, noise, duration, frequency) the repair is, and whether workers are punctual and polite. Understanding these challenges, various sustainable and customer-oriented repair solutions, such as hydro-scarification for quiet concrete demolition and the multi-pulse sequencing system for coping with water leakage, have been developed and implemented under the CSIP. Together with other cyclic maintenance and improvement programmes, the structural performance level of aging PRH buildings can be sustained and the service life can be extended as illustrated in Figure 2.

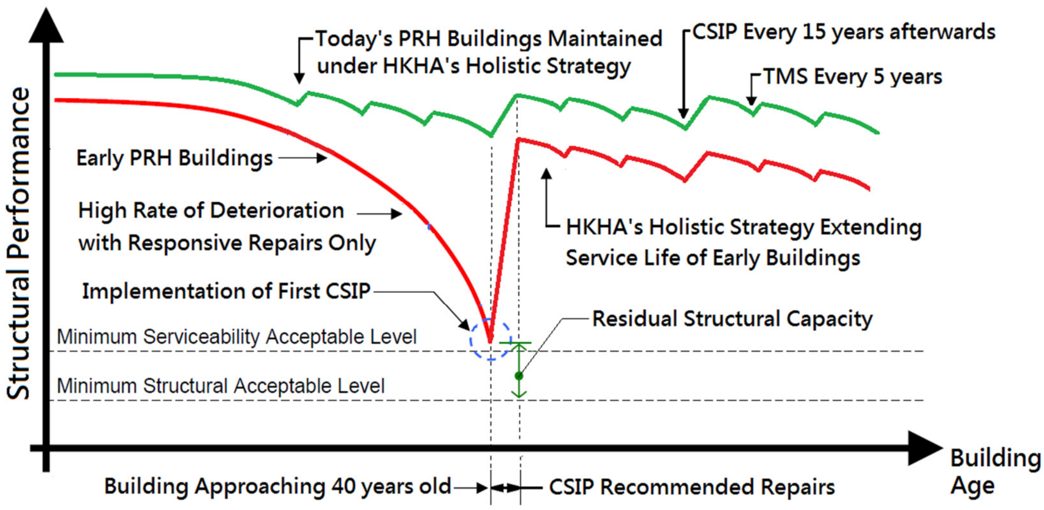

Figure 2: Service Life Extension of PRH Buildings

vi) Performance Monitoring

The CSIP is always about getting better performance through accumulation of data, knowledge and experience. In achieving this objective, long-term performance monitoring of the repairs has been implemented to improve future maintenance strategy. The monitoring includes visual surveys, moisture surveys, non-destructive tests, and tenant interviews. Based

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on the monitoring results, adjustments and enhancements can be made to the formulated repair methodology with due consideration given to the environment, performance, life-cycle cost, and disturbance to tenants.

2.3. Estate Improvement Programme (EIP)

With the structural life of aged PRH buildings being addressed by the CSIP, an EIP is implemented to upgrade the provisions and facilities of an aged PRH estate so that tenants can continue to enjoy a decent living environment that meets their up-to-date needs. Rather than taking a facility-based approach, a people-first and activity-based approach is adopted in the EIP design with a view to enhance community bonding. During the conceptual design stage, key concerns of a particular estate are identified through tenant surveys and EMAC consultation. Demography and unique estate features are studied and analyzed for a sustainable improvement scheme focusing on people. In particular, common areas and non-domestic premises are redesigned to suit tenants' changing needs stemmed from an aging tenant profile. Recreational facilities (e.g. fitness equipment for the elderly) are diversified to cater for different age groups and public space is reshaped to promote social interaction. Weather-protected passage and barrier-free access such as new lifts and ramps are integrated into a master pedestrian network to improve pedestrian circulation with the needs of the elderly and disabled tenants in mind. External façades and public areas are face-lifted to offer a pleasant living environment while in-flat facilities such as safety grab rails are fixed inside bathrooms for elderly tenants. Environmental concepts are incorporated for greener and more energy-efficient designs. For instance, the provision of green roofs on top of low-rise plant houses and non-domestic buildings can reduce indoor heat gain and at the same time improve the environment of a neighbourhood. Energy saving initiatives, such as energy-efficient corridor lighting, is put in place. Aging building service installations are also gradually replaced and modernized with a comprehensive programme to lower the total life-cycle cost. Energy-efficient lifts are installed under the Lift Modernization Programme, which enable a reduction of energy cost by over 30% when compared to the existing ones. Indeed, by adopting a people-first and activity-based approach, the EIP is able to rejuvenate the community, forge stronger ties in the neighbourhood, and allow tenants of all ages and backgrounds to enjoy their home.

3. Sustainable Living Approach

In striving for sustainability, the HKHA not only introduces and practises various environment-friendly measures in the daily operations, but also has developed and upheld a sustainability living lifestyle for tenants. As community support is crucial, the HKHA promotes sustainable living to the tenants through environmental protection activities, educational programmes and campaigns to boost their awareness and participation in reducing waste, recycling of materials and engagement of green initiatives covering the whole demographic spectrum.

i) Green Delight in Estates

The HKHA has launched a long-term community environmental programme “Green Delights in Estates” to promote environmental awareness among estate tenants through a series of educational campaigns and community activities, e.g. tree planting days and recycling competitions. These activities are organized in conjunction with local green groups to design and implement green initiatives for about 30 estates each year. While promulgating green practices, such activities also help building the community bond.

ii) Food Waste Recycling

The key drive for food waste minimisation is public education and engagement. A pilot scheme on food waste recycling using on-site composters was launched in two estates in December 2011. The scheme extends progressively and, at present, there are 14 estates using off-site food waste recycling for conversion into fish feed as well as on-site recycling for compost by micro-organisms. By end March 2014, over 3,000 households have registered to join the scheme. To boost tenants’ participation, the HKHA have conducted a series of estate-wide food waste reduction campaigns, such as “Food Waste has Value” green recipe competition, “Empty Your Plate” campaign and videos titled “Everybody Has Their Own Way to Save Food” and “Eat Light, Eat, Right” are broadcast on the Housing Channel in all estates.

iii) Tree Ambassadors and Community Planting

Over 500 tenants are recruited as “Tree Ambassadors” to promote arboriculture. To enhance their knowledge and interest, training courses on tree management are organized. Under “Community Planting”, tenants are encouraged to enjoy community planting and share the harvest at designated planting beds in the estates. A sense of belonging and neighbourhood are thus fostered.

iv) Recyclable Waste Exchange Incentive Scheme

To further boost the participation of tenants in waste recycling, tenants are encouraged to deliver their recyclable household waste to collection counters in all PRH estates to exchange for small incentives.

v) Source Separation of Domestic Waste Programme

To further facilitate waste recycling, HKHA has been actively implementing the Source Separation of Domestic Waste Programme. 31,660 tonnes of used paper, plastic bottles, aluminium cans and clothes were collected in 2012/13. Besides, the HKHA also actively participates in various programmes launched by the Environmental Protection Department, such as the recycling of rechargeable batteries, fluorescent lamps and computers.

vi) Green Study

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Pilot schemes are launched to explore various measures for rallying to sustainability. For examples, a green pilot scheme has been launched aiming to collect unwanted Lunar New Year citrus potted plants and replant them during the year. Over thousand pots of citrus potted plants have been collected in the pilot scheme.

4. Conclusions

The rally to establish sustainable public housing estates in Hong Kong is moving in full gear. With the aging of its tenants along with its housing stock, the HKHA is reinventing its aged estates through the three key initiatives: TMS, CSIP, and EIP. With the two million tenants at heart, all repair solutions and upgrades are customer-focused, addressing tenants' key concerns and needs. As the facilitator and enabler for a sustainable living approach, the HKHA is constantly driving fundamental changes in tenants' attitudes and behaviours towards a sustainable way of living through education and promotional campaigns. Though the journey is full of challenges, the HKHA endeavours to strive for continual improvement in the environmental, social and economic performance of the PRH estates and be the driver for sustainable living in Hong Kong.

5. References

[1] BSI, 2002. BS EN 1990:2002 'Eurocode – Basis of structural design. British Standards Institute.

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A Strong Research Environment for Sustainable Renovation Established in Sweden

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Abstract: *Sweden, as many other nations, faces large-scale, urgent need for renovation of post-war building stocks which have past their technical service life. To ensure the quality and effectiveness from different perspectives, environment, economy and the social, and enhance professionalism of the renovation process, a concretization of models for integrated sustainable renovation and development are needed. Such models will be developed within a research environment for Sustainable Integrated Renovation (SIRen) in Sweden. The approach is inter- and trans-disciplinary involving researchers at universities and institutes, actors in the construction and real estate industry, and relevant authorities, but still with a solid basis in disciplinary research. The research focuses on complex issues of renovation and redevelopment of existing buildings and urban areas conforming to objectives for reduced climate change, altered demographics and increased focus on democracy in planning, which are among the most important challenges for modern society.*

Key words: Sustainable integrated renovation, research environment, collaboration

Specific objectives and aim of the research environment

The recently established strong research environment for Sustainable Integrated Renovation, SIRen, gathers scientists from natural and social sciences and real estate economics at a large number of academic institutions and institutes in Sweden together with committed industry and public actors. SIRen focuses on the complex issues of renovation of existing buildings and redevelopment of urban areas conforming to objectives for reduced climate change, altered demographics and democracy in planning which are among the most important challenges for contemporary society to be handled within the economic context of construction without involvement of national subsidy. The approach is inter- and trans disciplinary, with a solid basis in disciplinary research. We challenge contemporary practices which fail to integrate societal objectives with environmental protection and aim at producing support to increase the sector’s ability to deliver sustainability. The research integrate technical, environmental, economic, architectural, and cultural issues in renovation with a starting point in the social dimension and focus multi-value approaches and multi-stakeholder involvement. SIRen has the overall aim to gather knowledge, to change national practice and to strengthen Swedish competitiveness for renovation practice and research internationally. Specific aims are to:

- Establish a knowledge base
- Document and analyse earlier and on-going cases of renovation
- Test and speed-up diffusion of innovation through demonstration and Living Labs
- Develop model/s, methods, tools for integrated sustainable renovation

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- Communication, dialogue and dissemination of results

The strong research environment will function in collaboration with the recently established National Centre for Renovation established at Lund University, and form a basis to develop additional research, innovation and attract new funding. After five years SIRen will pursue its activities and be a recognized partner for government, academy and industry in renovation. Other specific results are: a resource bank of up-to-date knowledge; inclusive model/s for integrated sustainable renovation including specific methods and tools; Living Lab and demonstrations; a platform for a Triple Helix dialogue to support sustainable renovation; and a basis for developing education in the field. Results aim to maximize the probability of replication of models and methods and trigger large-scale uptake market, targeting similar blocks and buildings and districts in Sweden or in Europe in need for renovation.

Overview of the research and problem area

Tackling refurbishment of existing buildings is a top priority in order to reach climate goals. In 2011, the Building performance Institute Europe's (BPIE) emphasised the critical role of refurbishment, when considering various pathways to achieve the 2020 decarbonisation goals [1]. To reach the 2050 target, renovation must be doubled or tripled compared to the current situation. Sweden, as many other nations in Europe, faces large-scale, urgent renovation of post-war building stocks which have passed their technical, economic and service life. The government or the building sector is not prepared for these challenges. We lack policy to handle housing shortage and affordability at the same time as regulations push for reduced energy use. In the building sector, knowledge in renovation is highly fragmentised, difficult to access for professionals, and production of new construction is normative. There is also an identified lack of manpower, and new competences are needed to handle complexity. The pragmatic reality of the market, the political visions and objectives, the municipal and private services, and the needs of inhabitants and citizens, all have to reconcile to create socially, environmentally and economic sustainable built environments. A short term and reductionist view favouring costs and efficiency could lead to devastating and irrevocable losses of existing and functioning social values and architectural/cultural historical qualities.

Five research areas

We have identified five areas for development of knowledge.

1. Dynamics of property management and the role of client

This area will build knowledge regarding: The renovation process/cycles from technical and economic perspectives and their social framing. Few scholarly papers have focused renovation and its specific challenges in relation to sustainability [2]. Compared to new construction, renovation is a process framed by uncertainties and risks. Last decades, renovation and energy efficiency has been neglected and not prioritised because of low energy prices. Existing methods for facility and property management does not reflect the complex reality. Current practices are reactive rather than proactive, knowledge of long-term effects of renovation/maintenance strategies are lacking. The other area is: The changing role of client to deliver integrated renovation. A main challenge for integrated renovation is the necessity

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for the client to manage a broader involvement of stakeholders representing different 'stakes', interests and power for action e.g. local authorities, residents, the local community, the property owner etc. The role of client should be expanded to include the users to address complex settings of current construction [3].

2. Integrated holistic design and effective renovation process

In renovation, it is necessary to analyse the building as a whole, including users, managers, technical systems, cultural aspects and economy [2]. This regards not only to the choice of technologies, but also renovation methods, design and socio-economic issues. The design phase affects the whole value chain. Energy-saving should be a natural factor to consider when prioritizing between different renovation actions. It is rare that renovation is preceded by necessary analysis. At the same time there exist methodologies that analyse energy optimization with profitability, life cycle assessment, life cycle cost and indoor environment [4]. Furthermore, renovation is not without risks. Even simple actions can alter the building function, affect moisture balances, cause comfort concerns and affect housing aesthetic qualities [5]. Another area is energy equipment and systems with focus on advanced heating and cooling as well as domestic hot water solutions. Technique is evaluated but there is a need to integrate result into a holistic design. A multi-scale cross-disciplinary approach fostering interactions among players need to be set up. A validated cross-disciplinary 'design for affordable sustainability' framework may support refurbished construction projects [6].

3. Economic challenges concerning renovation

Economic challenges regards contemporary practice to calculate profitability and the incentive structure for sustainable and energy efficient renovation and to overcome an energy-efficiency gap if there is one. The design of policy tools in relation to decision making is an identified research questions, based on knowledge of how decisions are made and on what basis they are taken [7]. Other important questions relate to the timing of decisions. In order to reduce economic burdens during a specific period the question of when certain renovation and energy savings measures should be applied.

4. Citizen/tenant empowerment and democratic decision-making

In recent years, the importance of the social dimension to realise sustainability has been emphasised. Contemporary housing renovation lacks a relevant discussion related to affordability, housing shortage and social stability and cohesion in housing areas, resulting in social exclusion and gentrification [8]. Dissatisfaction with traditional approaches has led to an interest in involving citizens in design and planning. Social inclusion issues closely relate to 'empowerment' – a process where inhabitants/tenants gain knowledge and skills to play a meaningful role in decision-making with the purpose of improving the environment and thus turned into producers rather than mere consumers of the urban environment. Improving a dialogue to the point of empowerment however requires more than mere tool development. It implies system changes in e.g. planning offices and housing companies which entail a need of including also such institutions as knowledge producers in research [9].

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5. Innovation and learning

A usual problem in construction is that good practices are not taken-up on a broad scale, another that broader visions for sustainability are seldom a goal in renovation. In order to support implementation of integrated sustainable renovation there is a need to understand the building sector in relation to innovation. There is a need to enhance understanding of innovation in construction, with focus on the innovation system and different actors' potential complementary roles. Learning and innovation should be understood with respects to social and cultural perspectives [10] and organisational capabilities [11]. There is need to rethink roles of all actors, from management down to the construction workers. New construction is normative, also in the training of new professionals thus defining training and education which emphasise learning and collaboration will be important.

Approach and methodology

This research proposal includes inter- and disciplinary knowledge building as important complements to trans disciplinary research. In traditional academic research, knowledge is often fragmented in its relation to theory and practice, whereas in action-oriented, trans disciplinary research approaches, the aim is to link research and practice and create new theory, tools and practices. A transdisciplinary approach implies joint knowledge production where all involved actors are considered producers, carriers and users of knowledge [12]. Implementation is therefore an integral part of the research process.

Realisation, performance and methods

The work will be carried out in five parallel work packages (WP) that are intertwined with the research foci (Figure 1).

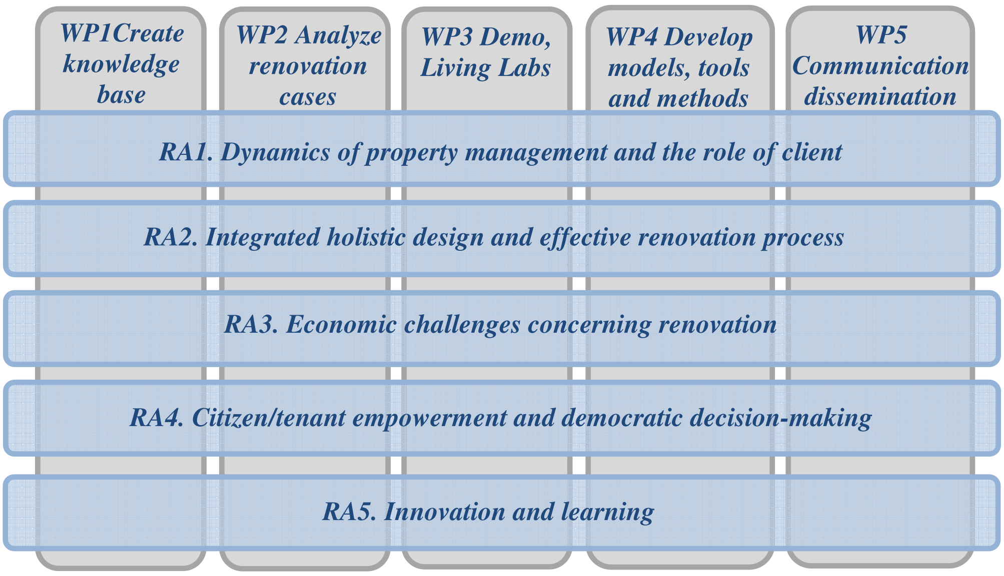

Figure 1. The connection between the five research areas (RA) focused on in SIRen and the work packages (WP).

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Results so far

The initiative came from a group of researchers from different disciplines and with different background and experience. More researchers were invited to participate in a core/steering group, and others were invited to join a resource pool of expertise. In November 2013, the research environment was granted 2.5 M Euro for five years by the Swedish Research Council on the condition that Swedish construction industry took part and contributed in form of in-kind resources corresponding to an equal amount of money. During 2014, a lot of effort has been made to convince the industry to write contracts and join the research environment.

At present SIRen consist of 11 researchers in a core and steering group and additionally 16-20 researchers invited in the expert pool to contribute to the work. Participants belong to: Lund University, Chalmers University of Technology, The Royal Institute of Technology, Luleå University, SP Technical Research Institute of Sweden, Umeå University, University of Dalarna, Gotland University, Malmö University. The researchers belong mainly to the fields of engineering and architect but also to economics, innovation and social sciences related to construction.

In May 2014, no less than 27 companies and organisations have joined the initiative:

- Four municipal housing owners of which one is a Mother concern for all municipal housing in Göteborg. Together they own and manage over 100.000 apartments.
- Two large nationally and interationally operating contractors (Skanska and NCC).
- Eight consultancies; two large technical consultancies one large architect consultancy and one small, one consultancy in the built environment, one specialised in renovation and one in post-war housing stock, and a small design consultancy.
- Three suppliers: one of solutions for facades, one for ventilation and one for bath- and kitchen renovation concepts.
- Sector organisations: The Swedish Client Construction Forum, The construction industry's organisation for R&D, The sector organisation for ventilation and plumbing companies, and the Swedish Tenant's Association.
- Municipal agencies: The city of Malmö, The Energy Agency of Skåne, The City Museum in Göteborg and The Region of Västra Götaland (division for heritage).
- Governmental agency: The National Board of Housing, Building and Planning.

The first kick-off meeting was held in May 2014 with around 40 participants from academia and industry. During two days we discussed and agreed on the most relevant research questions to start working with reflecting interest in the group and sub ordained to the pre-defined working packages. Working package leaders have been appointed and the participants have formed smaller trans disciplinary groups to take the ideas one step forward. The smaller groups will meet several times a year and the larger group of all participants 1-2 times a year. The kick-off was a large success and a new larger meeting is planned in 6 month.

An assistant has been attached to the project to administrate the research environment. A web-site has been attached to the National Renovation Centre (renoveringscentrum.lth.se).

One of the first results of the environment is a debate article in which no less than 11 of the involved researchers participated.

Concluding discussion

Sustainability in the built environment calls for the coordination of a variety of actors and processes of interaction and negotiation, and institutional changes. The discrepancy among stakeholders, diverse and sometimes contradictory discourses, agendas and interests create communicative barriers and has been identified as one of the most significant barriers to the realisation of sustainable practice [13]. This research environment focuses on integration between different disciplines, actors and stakeholders in renovation. Studies show that multi-actor and stakeholder involvement can lead to self-reflection which will facilitate the sharing of different world-views and disciplinary standpoints [14]. From a pragmatic view, broader stakeholder participation can enable solutions that are better adapted to local conditions and create empowerment among citizens and engagement. But most important, a broader collaboration will ideally lead to social re-valuation and initiate profound social learning: a necessity to sustain systemic and radical changes to deliver sustainable renovation.

The strengths of SIRen is the broad interdisciplinary setting gathering a large number of researchers and expertise in Sweden and strong industry commitment, as well as the large network connected to all parties. The setting provides an established platform for complementary research and innovation bidding in national and European calls. Common workshops and seminars have so far resulted in personal connections supporting informal knowledge exchange and a basis for spin-off activities. The involvement of industry enhances the relevance and usability of research, and will support up-take in the sector. The presence of municipality and governmental agencies potentially shorten the link between practice, research and policy making.

There are also a number of challenges for the research environment. While the strength is the broad participation, this also leads to challenges regarding coordination, administration and ethics of work. The ethics of sharing of knowledge and ideas, and the collaboration in publications has been illuminated and guidelines for behaviour for research have been presented at several occasions. The involvement of academia and practice presents challenges regarding reporting where outcomes need to be adapted to academic relevance being measured in scientific publications and the need of industry relevant reports and innovation support.

Further, the broad distribution of resources among institutions reflect the inter- and trans disciplinary approach but further funding will be needed for in-depth studies. At present, the research environment focuses mainly on housing and post-war stock, reflecting contemporary societal challenges but also the competence among researchers and participating property owners which represent housing owners. This has been brought forward as a limitation by some industry partners. A broadening of the scope will be solved mainly by future additional projects and funding.

ISBN: 978-84-697-1815-5

References

1. BPIE Building Institute Europe founded in 2010 by Climate Works, the European Climate Foundation and the European Council for Energy Efficient Economy (ECEEE).
2. Thuvander, L, Femenías, P, Mjörnell, Meiling, P (2012) Unveiling the renovation process, Sustainability. 4 (6), 1188-1213.
3. Newcombe, R. (2003). From client to project stakeholder. Construction Management and Economics, 21, 841-848.
4. Ostermeyer, Y, Wallbaum, H, Reuter, F, (2013). Multidimensional Pareto optimization as an approach for site specific building refurbishment solutions applicable for LCSA. The Int. Journal of Life Cycle Assessment, 2013, 18, pp. 1762-1779.
5. Hagentoft, C-E , Annex 55 Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance & Cost (RAP-RETRO), http://www.ecbcs.org/annexes/annex55.htm.
6. Energy-efficient Buildings PPP beyond (2013), Research and innovation Roadmap.
7. Högberg, L. (2011), Incentives for energy efficiency measures in post-war multi-family dwellings, KTH, Stockholm.
8. Lees, L., T. Slater and Wyly, E., Eds. (2010). The Gentrification Reader. New York, Routledge.
9. Fung, A. (2006). Varieties of Participation in Complex Governance. Public Administration Review (Special Issue): 66-75.
10. Harty C (2005). Innovation in construction: A sociology of technology approach, Building Research & Information, 33, 512-522.
11. Davies, A and Brady, T 2000. Organisational capabilities and learning in complex product systems: towards repeatable solutions. Research Policy, 29, 931–953.
12. Carew, A.L. and Wickson, F. (2010). The TD Wheel: A Heuristic to Shape, Support and Evaluate Trans disciplinary Research. Futures 42: 1146–1155.
13. Häkkinen, T. and Belloni, K. (2011). Barriers and drivers for sustainable building. Building Research & Information, 39, 239-255.
14. Construction Management and Economics (2008) 26, 549-676, Special issue on Stakeholder Management in Construction.

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"Propagation" as a key factor to accelerate the transition to low-carbon resilient cities

Speakers:
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Abstract: *Certification schemes for urban development under sustainability paradigm generally remark the three classical axes: social sustainability (People), environmental sustainability (Planet) and economic sustainability (Profit). However, there are some key factors undervalued in those three axes that affect the long-term performance of a project. To the well-known "triple P", the 5P approach of Eurbanlab promoted by Climate KIC, adds a forth category, the assessment of the Process, and a fifth one, the Propagation. This paper discusses how propagation, originally conceived as a part of the process assessment, has become an own category to avoid that urban best practices remain as single trials instead of making transition to low cities happens.*

Assessment tool, Urban innovation, Propagation indicators, Eurbanlab, Climate KIC, Urban best practices, making transitions happen.

The isolation of the urban best practices

Significantly, there are many innate resistances to change daily habits and to make transition happens. Previous findings discuse how post-industrial theories that consider the technical and urban innovation as instant phenomenons are still in current political agendas (Castells 1996). The empirical experience evidences how the acceptance of urban innovations requires a minimum of time and a maximum of dissemination. If the innovation doesn't have enough time to be implemented or it needs a long time for dissemination, the innovative project becomes an empty concept and the innovation fails during the process of implementation. In fact, it is as dangerous a lower impact than an overflow. This phenomenon is embodied in the short film called Six Apartments by R. Reynolds. The situation exposed by the film can metaphorically represent how the overexposure of citizens to the dangerous effects of climate change can guide them to apathy (Fig. 1).

Figure 1. Six Apartment, short film. (R. Reynolds).

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This piece of video shows two screen video projection loops transferred from 16mm. According to those visualizations, the audience could detect parallels between characters, spaces and situations. Tenants remind indifferent to the catastrophic messages about climate change that come out from the radio, focusing on their small private life. The common habits become loops that are imposible to break up. Consequently, communication is missed.

Although the risks mentioned before are real and awareness about climate change mitigation is growing in the society, best practices in sustainable urban development initiatives usually are disconnected or isolated; they work in parallel and don't achieve to be scaled up to other contexts. As a consequence, urban regeneration and innovative proposals are usually presented as unique and remarkable pilot cases, but not as widespread strategies that can easily be extended to other places. Moreover, despite urban regeneration initiatives have full support from the European political spheres (eg. strategy Europe 2020) and they can be evaluated by several urban certification systems (such as LEED, BREEAM, CASBEE, etc.) and by methodological supporting guides (Libro Blanco de la Sostenibilidad en el Planeamiento Urbanístico Español, INDI-RU 2005, etc.), these initiatives don´t achieve to scale up their application.

According to this context, why is it such a challengue to scale up urban innovation and regeneration projects? Taking into account the high complexity of these projects and their large implementation periods, one of the most remarkable reasons is the difficulty to systematize their process (Aparicio & di Nanni 2011). This topic is crucial to justify the economical viability of these projects, and also in order to develop a better communication strategy to spread lessons learned (Rogers 1995). This paper therefore takes as a starting point the essential hypothesis that these tools reflect partially successful parametres in urban regeneration projects. From this point of view, the first step is identifying key factors remarked by existing certification tools and indicator systems. The following figure (Fig. 2) shows a comparative analysis of eight different indicator systems. The table identifies the number of indicators used to evaluate the most important categories in urban regeneration projects (Mateo et al 2014). The short number of indicators focused on the *Process* category reveals that this category is undervalued. In addition to this hypothesis, other studies suggest that the underuse of these assessment tools may be due to the fact that their results are biased or incomplete (Simon 2010).

	ground occupation	public space	social cohesion	urban mobility	urban metabolism	process and method
ECOCITY	3	6	5	7	2	4
INDI-RU	2	19	6	3	0	0
LB	4	21	15	26	5	10
SIM	5	0	2	4	0	1
LEED-ND	6	3	11	11	1	1
BREEAM	5	11	14	15	1	1
CASBEE	4	10	6	39	1	1
AEUB	4	27	10	25	10	0
TOTAL	37	97	69	130	20	18

Figure 2. Different weights of urban indicators categories. Urban Regeneration Guide, Mateo et al. (unpublished). (Valencian Institute of Building)

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Eurbanlab project and its 5P approach

Despite public administration efforts to create more complete indicator systems for fostering urban regeneration projects, the previous objections still stand. The key topic is promoting a scenario where urban regeneration is identified as a clear process with a systematic procedure to be scaled up. That is one of the main goals for the Eurbanlab project. This initiative is a Pan-European alliance co-funded by Climate-KIC, one of the three Knowledge and Innovation Communities created in 2010 by the European Institute of Innovation and Technology. This initiative is being developed by partners from Paris, London, Rotterdam, Utrecht, Berlin and Valencia. The aim of this project is to accelerate the updating of knowledge innovations in sustainable development, urban regeneration projects and retrofit. Eurbanlab thus develops several initiatives to promote the transition to low-carbon resilient cities. One of them is the assessment tool called B4U or "Benchmark for you" (Bosch et. al 2013). This B4U indicator system provides an assessment of innovative projects in their local context and it is particularly focused on indentifying the factors for the urban regeneration projects success. As previously mentioned, indicator systems which mainly focus on social, economical and environmental aspects (*People, Profit* and *Planet* categories) are just insufficient. From this point of view, the B4U assessment tool adds more variables which measure the economic viability of these projects, their implementation processes and also their impacts in society (*Profit*, *Process* and *Propagation* indicator categories). Consequently, this is the 5P approach of Eurbanlab (Fig. 3).

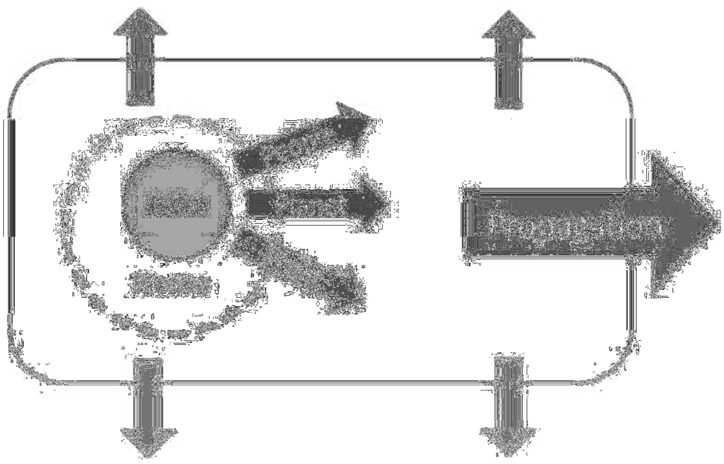

Figure 3. Impact of an innovative project (Eurbanlab)

The B4U assessment tool and its Propagation indicators

The evaluation of the process of such urban regeneration projects is arguably more complicated than for other types of urban developments. More crucially, traditional procedure methods and approaches are still present in the design, financing or implementatation phases of these initiatives. According to this fact, these outdated processes become barriers for a successful development of the urban innovations projects (Gordon 2005). Furthermore, the quality of the development process determines the long-term outcomes of the projects. Consequently, the key topic is to include new factors to assess urban regeneration and innovation projects from the point of view of the procedures. With respect to this category, the *Process* indicators aim to capture those aspects of the project that has contributed (or will contribute) to a successful process of implementation. It is compelling enough the argument to foster new schemes or certification methods that specifically focus on *Process*. The B4U assessment tool develops a methodology that provides a complex evaluation of the process to answer this need. And more specifically, even one of the 5P's of the Eurbanlab approach is a process stage in itself, the category of *Propagation*. The *Propagation* indicators add a differential value to other indicators systems, analyzing the final phases of the project implementation. According to this, this paper will be focused on *Propagation*. The results and conclusions about the other catergories are also available in other publications and books of abstracts (Mateo et al. 2014).

By focusing on the *Propagation* category, the evaluation of this final part of the process can significantly contribute to support the transition towards low-carbon climate resilient cities. This category reveals that the acceptance and adoption of innovations is not an immediate action as we mentioned in the introduction, but rather a gradual process which can take a considerable period of time to become generally accepted and standard practice. By focusing on *Propagation* indicators, the B4U assessment tool determines the potential for the propagation of innovations and identifies factors that can be extrapolated to other projects. A large number of those indicators are directly or indirectly derived from the diffusion of innovations theory by E. M. Rogers. The diffusion of innovation theory is a relevant choice for this group of indicators within the B4U as it examines the adoption behaviour of actors who are in the process of implementing an innovation, and determining whether that implementation will be a success. Taking Rogers definition of diffusion, the *Propagation* of innovations is the process by which an innovation is communicated through certain channels over time among the members of a social system (Fig. 4). According to this tenet, the diffusion process is characterized as a five-step process that suggests how an innovations spread amongst potential adopters in society or a specific industrial sector, over a certain period of time (Rogers 1995).

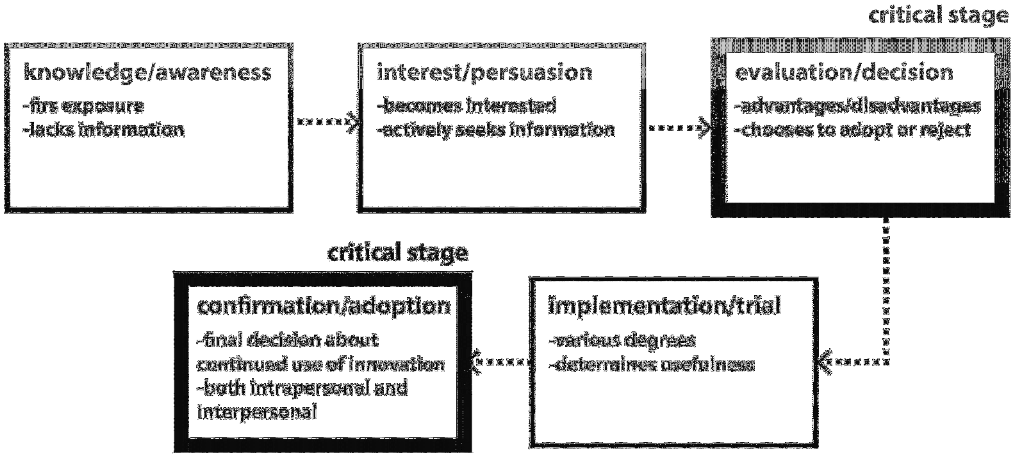

Figure 4. Five stages of the diffusion process (adapted from Rogers)

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The relative velocity to adopt an innovation by society is described as the rate of adoption, and is determined by a number of variables. However, most of the variance in the rate of adoption of an innovation, from 49% to 87%, can be explained by the five perceived attributes of the innovation (Rogers 1995). The likelihood that an innovation will be adopted thus depends to a large extent on its perceived attributes (Fig. 5): *Visibility, Compatibility, Complexity, Relative Advantage and Trialability.*

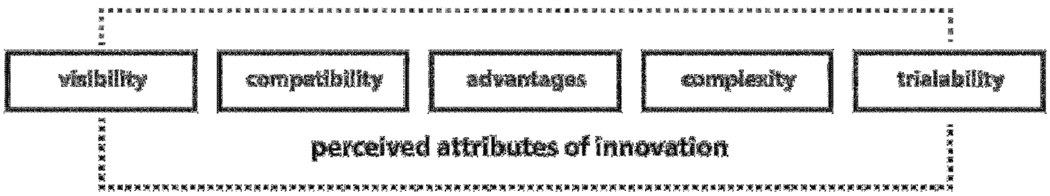

Figure 5. Perceived attributes of innovation (adapted from Rogers)

Taking into account these theories, Eurbanlab identifies innovations which have the potential for up-scaling within Europe. The *Propagation* indicators are focused on the factors that achieve a better implementation of the urban regeneration or innovation project and that foster a better assimilation by the users and stakeholders. The rationale behind this cluster of indicators is that innovations themselves contain a number of characteristics that determine the extent to which the innovation fits within the implementation context and influences the decision to adopt or reject an innovation. Because the rate of adoption is significantly determined by these perceived attributes, the B4U will evaluate these atributes as indicators, in order to define its potential for diffusion (Bosch et al. 2013). For instance, several of these indicators have been directly developed from the five attributes previously mentioned, such as the *Triability*, the *Visibility* or the *Complexity* indicators. Once the *Propagation* category is evaluated by the indicator system, the tool provides the option to compare the results through a normalization process. This step is vital not only to compare factors with widely varying units and scales but also to compare different projects in order to identify their weaknesses and strengths. Furthermore, this methodology allows the assessment of large cases of regeneration and also smaller urban scale interventions.

How do Propagation indicators influence other categories?

The B4U assessment tool has been currently applied in more than 11 projects of urban innovation, five of them in the Netherlands, one in Sweden, two in the UK, one in Belgium, one in Germany and one in Spain. Interestingly, most of them are urban regeneration and retrofitting projects. In order to answer the question of how the Propagagation indicators empower other categories, this paper compares two case studies paying special attention to *Propagation*.

De Kroeven is an urban regeneration project of 134 social housing, built in the early 1950s. It is a private initiative launched in the town district of De Kroeven, in Noord-Brabant, Netherlands. In this case, *Propagation* indicators score higher comparing with the other case studies and also comparing with the other categories in the same project. This score is due to its high investment in the technical solutions. Some environmental innovations offer a clear advantage to those using innovation (*Advantages for end users*). In the context of solar PV for example, environmental benefits can be combined with user benefits through the reduction of

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energy bills. Furthermore, this project achieved a great result in the *Technical compatibility of innovation* indicator. This parameter provides an indication of the technical compatibility of the innovation, meaning the extent to which the innovation fits current practices, administrative and existing technological standards or infrastructures. It is important to highlight that while the other 5P's categories are unbalanced (score under the average) this project achieved a successful implementation. This fact reveals the great importance of Propagation factors for the success of urban innovation and regeneration processes (Fig. 6).

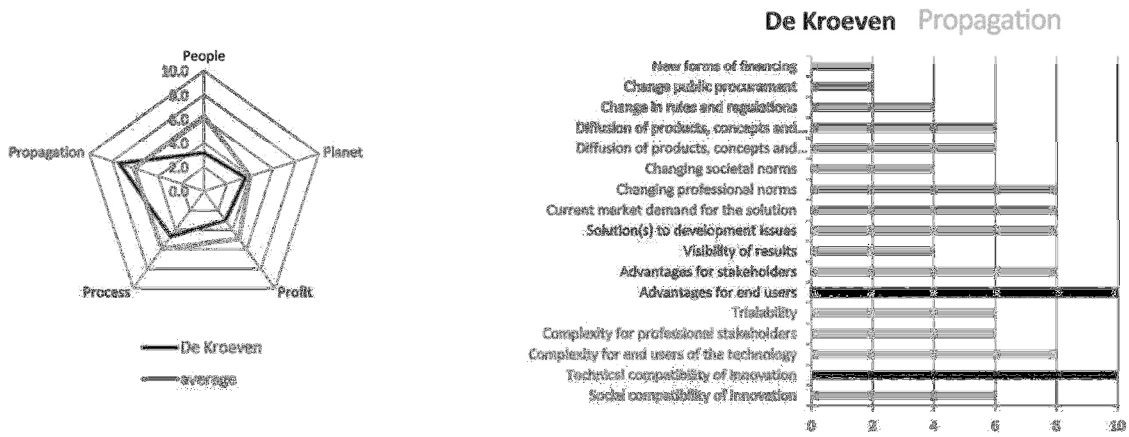

Figure 6. Results per P-category and Propagation indicators scores. De Kroeven assessment (Eurbanlab).

The Bomenbuurt Ulft project was launched as an innovative procurement method in the restructuring of a neighborhood from the 1960s. This case obtained one of the highest Propagation scores of the all the cases. Through a different form of procurement (Fig. 7), the market was challenged to come up with innovative and integral solutions for energy neutral building with a very competitive price. As shown in the figures below, the great result achieved in the *Propagation* and *Process* categories also holds great results in the *Profit* and *Planet* indicators. The greatest influence was detected on the *Planet* category due to the energy saving strategies applied in the project and also due to the renewable energy produced on-site. The positive results are more than 30 per cent compared to the average in *Planet* indicators. Most of these factors have also a great influence in the *Visibility* of the project in the market.

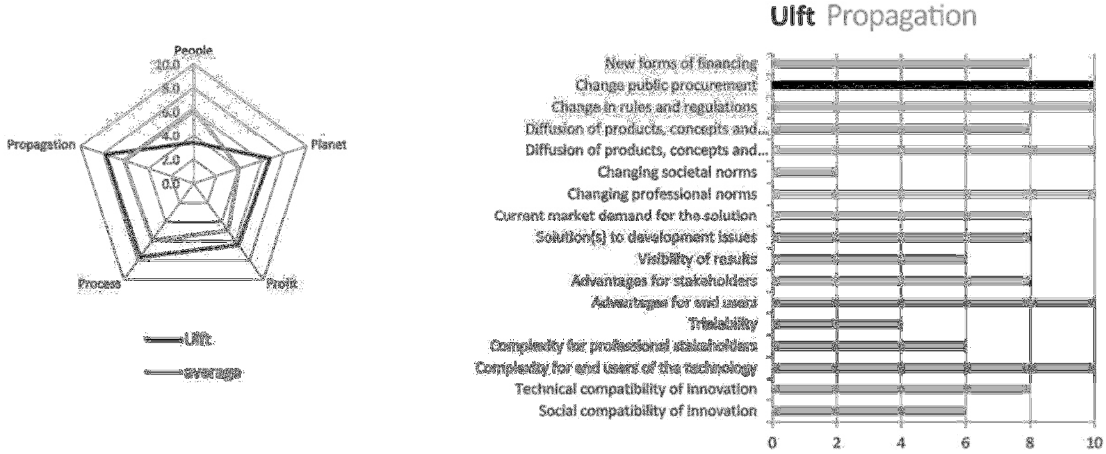

Figure 7. Results per P-category and Propagation indicator scores. Ulft assessment (Eurbanlab).

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Results
Eurbanlab develops several initiatives to promote the transition to low-carbon resilient cities. In order to make it happens, it is necessary to develop better procedures to implement sustainable innovations and urban best practices. In the case of the urban regeneration projects, the key topic is how to improve the process (during all the phases: design and implementation); and how to achieve a better assimilation of the innovation by the users. To answer these questions, Eurbanlab develops the B4U assessment tool including 2 procedure categories in its approach: Process and Propagation. Focusing on the diffusion of the innovation, Eurbanlab propose the measuring of several aspects as e.g: the *Advantages for end users*, the *Technical compatibility of the innovation* or the *Visibility* of the results. These factors indirectly empower the environmental indicators (*Planet*), the *Profit* indicators and the whole *Process* category. This approach is valuable to identify the critical situations that can hamper the process during the project development. In urban regeneration projects, the lessons to learn from the Eurbanlab assessments can be used to overcome the “death-valley” situations. This financial concept refers to the period of time before a new company or product is implemented and starts to generate revenues. If this period of time is too long, the innovation fails and remains out-of-market, and this phenomenon is extrapolable to urban innovations. According to this, the B4U assessment tool and its *Propagation* indicators can be used for analyzing the minimum of time required to implement the innovation and the maximum of impacts (in a communication sense) that are necessary to be accepted. To sum up, this method can offer a better analysis of the barriers which could limit the potential of urban regeneration practices and urban innovation initiatives to be extended. In a political level, these results can be used to change rules and regulations, to define new public procecurements and to change societal and professional norms. Several *Propagation* indicators such as *New forms of financing* or *Current market demand for the solution*, could also be used to detect innovative niche markets to develop low-carbon economies such as Climate-KIC pursues.

In summary, the traditional approach of the urban assessment tools can be easily improved adding process and propagation factors as we mentioned before. It also will encourage the decrease, reduction and removal of market barriers and the promotion of new regulations to stimulate urban regeneration and innovation initiatives, aligned to the European research and innovation policy framework Horizon 2020.

References
Aparicio, Á. & di Nanni, R. (2011). *Modelos de gestión de la regeneración urbana*. Madrid. SEPES, Ministerio de Fomento.
Bosch, P. et al. (2013). *The Eurbanlab Selection of Indicators. Version 2.0*. Unpublished. Utrecht. EURBANLAB.
Buck, N. et al. (2005). *Changing Cities. Rethinking Urban Competitiveness, Cohesion and Governance*. New York. Palgrave/MacMillan.
Castells, M. (1996). *The Information Age: Economy, Society and Culture. Volume I: The Rise of the Network Society*. Cambridge. Blackwell Publishers Inc.
Mateo, C. et al. (2014). *Guía de Regeneración Urbana Integrada de la Comunidad Valenciana*. Unpublished. Valencia. Instituto Valenciano de la Edificación.
Mateo, et al. (2014). *Transitando hacia economías de bajo carbono: Eurbanlab y el sistema B4U*. Book of abstracts. 2nd EECN Conference. Madrid. GRUPOTECMARED.
Rogers, E.M. (1995). *Diffusion of Innovations*. New York. The Free Press.
Simón, M. (2010). *Herramientas para evaluar la sostenibilidad de las intervenciones urbanas en barrios*. SB10mad Conference. Madrid. GBCe.

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2. Literature Review

2-1. Macro to Micro, well-balanced spatial planning

Macro-scale strategies are corresponding to the territories of a number of economic transactions where resource flows or externalities are experienced (IPCC, 2014). There are two specific types of urban growth patterns. Monocentricity represents a traditional urban form usually containing a single city centre. However, this form has been changing in accordance with cities' growth due to suburbanization and urban sprawl. This trend has led to increased travel distance and automobile ownership. On the other hand, polycentric urban form has several sub-centres. This enhances feasibility of urban transport and could realise more sustainable neighbourhood design. In fact, a number of existing polycentric metropolises such as Paris, Tokyo, and Singapore have successfully linked their sub-centres with high quality public transport (Carvero, 1998). Fundamental urban development principles could be drawn from such macro-scale spatial plans. However, one of the key challenges for regional planning is the relationship between job location and housing location. Hall (1991) indicated that population density and job locations have significant influence on travel distance and modal split. Automobile-based cities tend to have a strong central business district with a very high job concentration and little affordable housing. On the other hand, public transit-oriented cities tend to have a much better balance between central city jobs and residences (Newman and Kenworthy, 1991). However, this balance heavily relies on where jobs are located (Hall, 1991).

Recently, micro-scale design has begun to focus on the elements of "green neighbourhood." Many cities are promoting urban regenerations by investing in pedestrian and cycling infrastructure and emphasizing attractive public realms such as green spaces and comfortable public community spaces. London has succeeded in recycling old industrial buildings into mixed-use urban cores with middle income housing and high quality transit services (Foletta and Field, 2011).

2-2. Climate change challenges for neighbourhood

Strong focus is placed on transit-oriented development as one of the local strategies for combating climate change. A number of existing European cities have been transit-oriented for a long time. Most of them have such features as mixed land use, pedestrian paths, and ample transit options (Cervero, 2006). The crucial role of spatial planning for reducing energy use and GHG emissions is evident from various case studies in the developed world. These studies highlight the importance of an integrated infrastructure development framework maximizing both mitigation potential and long-term public services (IPCC, 2014).

2-3. Technological transitions

In order to ensure an integrated infrastructure development that occurs in an environmentally sustainable way, various technological transitions need to be promoted.

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A scenario of long-term integrated spatial planning strategies for sustainable communities

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Abstract: *Integrated spatial planning strategy is becoming a central theme for sustainable development. In recent years, a number of attempts of urban regeneration projects have been initiated by local governments in the world, aiming at creating sustainable communities, improving quality of life, and tackling the issue of climate change.*

However, this issue needs to be addressed, taking into account local scale, local history, as well as its cultural aspect. While technological transition can be a strong driver for enhancing energy efficiency and reducing greenhouse gas (GHG) emissions, its affordability, including the cost analysis of upgrading housing and physical infrastructure, must also be taken into account. This paper attempts to develop a long-term transition pathway for local spatial planning that could most likely achieve zero/low carbon principles over the next 100 years.

Keywords, Climate change, Integrated spatial planning, Zero/Low carbon principles, Quality of life, Sustainable communities, Long-term scenario strategy

1. Introduction

Greenhouse Gas emissions (GHG) from construction more than doubled from 1970 to 2010 (IEA, 2012). In 2010, buildings accounted for 32 percent of global energy use and 19 percent of energy-related GHG emissions. Furthermore, they may double or even triple by the middle of this century due to several key factors (IPCC, 2014). Many scientists and engineers highlight the risk of significant lock-in effects due to long lifespans of buildings and retrofits. To overcome these challenges, we need to take into account not only building technology and architecture but also such factors as behaviour, lifestyle, and culture. In this context, neighbourhood scale management has strong potential for developing more energy efficient, environmentally friendly transition pathways with long-term visions. It could enable development of a roadmap for upgrading basic infrastructure with sustainable solutions such as renewable energy use, transit-oriented development, and so forth. This promotes the possibility of significant CO2 emission reductions on the neighbourhood-scale using long-term scenario pathways with the time scale of 100 years.

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2-3-1. Aiming at net-zero/low carbon and positive energy buildings

Net zero energy building could be simply defined as the one with on-site renewable energy systems generating as much energy as it consumes. However, the Zero Energy Building (ZEB) concept is actually described using a wide range of terms and expressions. Careful distinction is necessary among different approaches in defining ZEB. Calculating the energy balance of building with on-site/off-site renewable energy generation is not easy. There is no clear standardized calculation methodology (Marszal et al., 2011).

The main conceptual difference of a net zero building derives from whether it is off-grid or on-grid. The off-grid zero energy building uses electricity storage systems instead of a grid connection. This is why it is called 'self-sufficient' or 'stand-alone' building. An extension of the net zero energy building concept is the positive-energy building concept, where on-site renewable energy systems produce more energy than it consumes (Kolokotsa et al., 2011). 'Zero-carbon building' is a desirable goal, but not easy to regulate. A target such as 85-90 percent reduction may be more practical and achievable (Lowe and Oreszczyn, 2008).

2-3-2. Existing building challenges

Existing buildings have enormous potential for improving energy efficiency. There are also many opportunities for upgrading existing building stocks. This includes not only simple retrofit procedures such as using high energy efficiency equipment, but also changing the function of a building itself in an efficient way, installing sustainable energy systems and applying the most advanced IT system. However, it is essential to consider more intelligent sustainable housing solutions ensuring effective links and co-benefits with the surrounding neighbourhood and townscape. Moreover, there could be a conflict between retrofitting cultural heritage or historical building stock and pursuing environment policy goals (Ravets, 2008). The property market has much impact on the building yield factors, equity, and future maintenance.

2-4. Integrated spatial planning strategies and implementation

Effective spatial planning can be achieved with interlinked and coordinated efforts (Porter, 1997). The sustainable community strategy is discussed as an integral part for achieving sustainable development. This concept involves the physical regeneration of urban infrastructure, retrofit or demolition of existing properties, and creation of new urban green and open space, all of which enhance the quality of life and boost urban economies (Maliene and Malys, 2009). The UK government launched an ambitious sustainable community programme in 2003. This identified the eight key elements of a sustainable community: 1) economy, 2) governance, 3) transport, 4) connectivity, 5) services, 6) equity, 7) environmental, and 8)built environment (ODPM, 2004). Sustainable communities must be well-planned, safe, and inclusive and offer basic social services such as hospitals, schools, shops, public transport, and a clean and safe environment (Maliene and Malys, 2009). The most fundamental need is to provide affordable housing to a diverse range of people as well as offering effective open public spaces. Gakenheimer (2011) argues that successful

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institutional coordination and political leadership by higher levels of governance is essential for building spatial strategies with positive synergies.

3. Study Methodology

This paper presents a case study of scenario analysis for achieving net zero/low carbon principles in sustainable community planning. A site with the scale of approximately 7 hectares and around 2,700 people is selected in the centre of London. As a first step, master planning analytical methods are applied. This analysis includes context, transport link, land use, building typology, and climate condition.

Secondly, sustainable strategies are developed adapting to the specific context. Then, physical master plans are developed in four phases covering 100 years. This master plan aims at more than 70 percent reduction of total carbon footprint on site by the target year. Finally, using these long-term visions, net energy balance and carbon foot print are calculated alongside the analysis of personal quality of life and cost feasibility with market condition.

4. Case Study Analysis

4-1. Overview of the case background and first step of analysis

As mentioned above, the area (Plot K) includes mainly traditional English social housing with around 2,700 inhabitants. There are several links connecting public transport with the city centre district and suburban areas (see Figure 1). As for the social services, this area does not have convenient access to local shops, hospitals, culture spaces, or various offices.

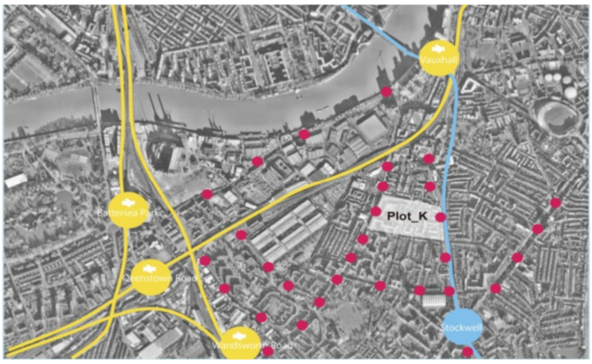

Figure 1: Transport link (Made by author with google map)

Figure 2: Shade analysis (Made by author)

However, this area is very quiet. Since there are no high-rise buildings (see Figure 2), solar power generation might have high potential to be installed. The most controversial issue in this area is that most housing was developed by the general public and holds historical values. Therefore, a regeneration strategy must apply retrofit upgrading with minor changes of building surfaces.

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4-2. Transition pathways through 100-year time phase

An urban regeneration master plan is developed in four phases (see Figure 3).

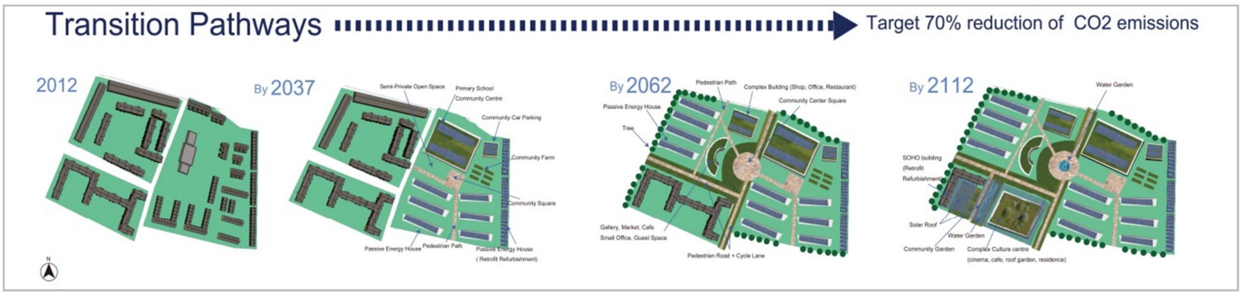

Figure 3: Transitions Pathways with four time phase (Made by author)

This future master plan uses the sustainable neighbourhood strategy, sustainable energy strategy, and sustainable transport strategy.

4-2-1. Sustainable neighbourhood strategy

The sustainable neighbourhood strategy represents multiple community design with a high quality of public spaces, better connectino with public transport and essential services, and well-designed sustainable buildings. Mixed land-use spatial planning enables more flexible use of urban areas, increases options for different households, and creates a sense of locality. More importantly, diversity of space functional options could reduce travel frequency and trip length. Open space strategy is also effective for environmental bio-diversity and wind paths. Expanding the network among open spaces can also provide pedestrian space and safe playgrounds for children. Integrated neighbourhood sustainable planning also requires waste management and recycling as well as water management systems including waste water management, rain water collection, and flood risk management.

4-2-2. Sustainable energy strategy

This long-term community master plan heavily focuses on sustainable energy systems. Installing renewable energy is one of the key features. Most of the retrofitted buildings and newly built properties install solar PV systems on their roofs. However, there is big gap between peak heating demand and the peak of solar power generation. Mackay (2009) indicates that solar intensity in the UK is very low for accommodating high heating demand during winter. In this master plan, two levels of retrofits are applied, namely, high energy efficiency retrofit with high cost and conventional retrofit with lower cost. The decentralised energy system plays a vital role for sustainable community development. The Combined Heating and Power system can reduce capital expenditure and provide high infrastructure flexibility.

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4-2-3. Sustainable transport strategy

Each location must be linked to public transport within reasonable access distance. Specifically, each bus stop should be reached within around 50 to 100 metres from each housing or service facility, while underground or national rail should be located within around 300 to 400 metres. For encouraging use of public transport, a safe and comfortable pedestrian/cycling link to the public transport is also an essential component. Community car parking is developed to minimise car use and create open spaces for neighbourhood instead. This master plan also aims at increasing indispensable services such as shops, restaurants, culture, small offices, and even community farms. All the above could notably reduce lifestyle-based carbon footprint. Moreover, safe public roads and linking spaces could provide playgrounds for children. This will incentivize families with children to inhabit here.

4-3. Analysis of future scenario

The most significant expected impact of this master plan is the notable reduction of total thermal and electrical demand and the increase of electrical and thermal renewable energy (see Figure 4). Furthermore, the total energy demand will be dramatically reduced by energy efficiency retrofitting in addition to changing of space function adapting to mixed use strategy. The mixed use spaces could make for a better balance of energy and water demand during a day and a year. Cost benefit balance analysis presents the feasibility of construction projects, which are essential parts of the implementation of this master plan. The analysis indicates that the sales value will gradually increase during the first phase through a housing retrofit and then decrease in the remaining phases. Construction costs will show continuous increase throughout all phases (see Figure 5). The final profit balance shows approximately 20 percent reduction. However, this does not include non-physical value such as well-developed public open spaces with better environments, which may increase market value. Moreover, this does not take into account energy bills, which may have significant influence on households' decisions for buying properties. This long-term scenario suggests 90 percent reduction of carbon footprint per person can be achieved with only 7 percent reduction of inhabitants and more public open spaces in this area (see Figure 6).

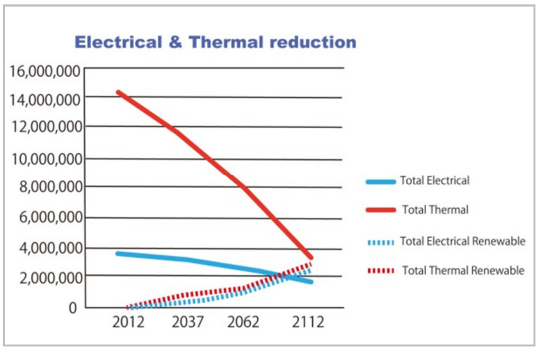

Figure 4:Electrical & Thermal reduction

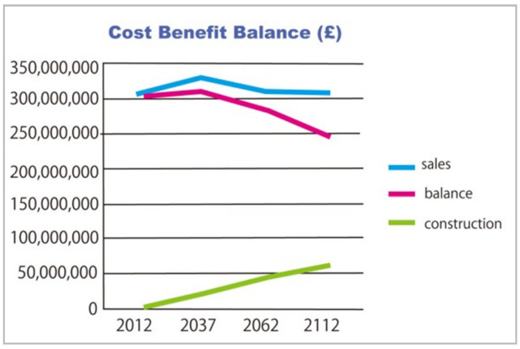

Figure 5: Cost benefit balance

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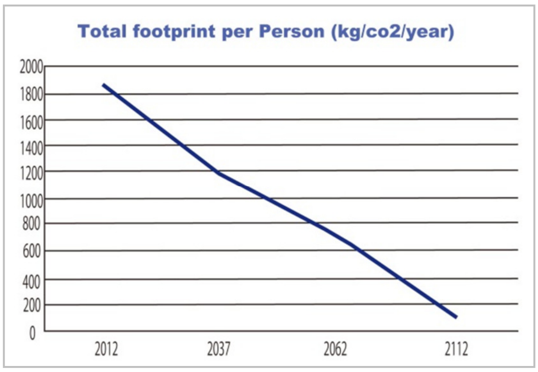

Figure 6: Total footprint per person

5. Conclusions

To sum up, this case study presents the significant potential of reducing energy demand and carbon footprint per person by upgrading building functions. The sustainable regeneration master plan is likely to adopt a wide range of advanced technologies, including renewables and ideas. Application of this model to other areas needs careful consideration of local context including climatic condition. Finally, this scenario case study and its cost-benefit analysis indicate that significant reduction of carbon footprint is achievable and economically feasible. In addition, it needs to be noted that its cost-benefit analysis does not incorporate such elements as higher quality of life and consequent higher market value of properties. If such elements are incorporated, the benefit of this scenario will become further convincing.

6. Acknowledgement

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7. Refarences

Carvero, R., (1998) *The Transit Metropolis, A global Inquiry*: Island Press, Washington, D.C., 480pp.

Carvero, R., (2006) *Public Transport and Sustainable Urbanism: Global Lessons*: University of California Transportation Centre 1-10 pp.

Foletta N., and S. Field (2011) *Europe's Vibrant New Low Carbon Communities*. New York : Institute of Transport and Development Policy 116pp.

Hall, P. (1991) *Transport and Urban Development,* ed. Banister, D. 65-89, UK: E&FN Spon

IEA (2012) *World Energy Outlook 2012*. OECD Publishing, Paris.

IPCC (2014) *Climate Change 2014: Mitigation on Climate Change*, Working Group III Contribution to the IPCC 5th Assessment Report. Available at: https://www.ipcc.ch/report/ar5/wg3/

Kolokosta D., D. Rovas, E. Kosmatopoilos, and K. Kalaitakis (2011) A roadmap towards intelligent net zero- and positive-energy buildings, *Solar Energy* 85: 3067-30854 pp, doi: 10.1016/j.solener.2010.09.001

ISBN: 978-84-697-1815-5

Lowe, R. and T. Oreszczyn (2008) Regulatory standards and barriers to improved performance for housing, Energy Policy 36: 4475-4481, doi: 10.1016/j.enpol.2008.09.024

Maliene, V. and N. Malys (2009) High –quality housing – A key issue in delivering sustainable communities, Building and Environment 44: 426-430, doi: 10.1016/j.buidenv.2008.04.004

Marszal A.J., P. Heiselberg, J.s. Bourrelle, E. Musall, K. Voss, I. Sartori, and A. Napolitanp (2011) Zero Energy Building – A review of definitions and calculation methodologies, *Energy and Buildings* 43: 971-979pp, doi: 10.1016/j.enbuild.2010.12.022

Newman, P and J. Kenworthy, (1991) *Transport and urban form in thirty-two of the world's principal cities,* Transport Review: Taylor

ODPM, Office of the Deputy Prime Minister (2004) The Egan review: skills for sustainable communities. London: RIBA Enterprise Ltd.

Poter D.R. (1997) *Managing Growth in America's Communities*.:Island Press, Washington, D.C., 311pp

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Session 14:

Urban renewal, how is it managed?

Chairperson:

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Sustainable valorization of *unique heritage*: oasis cities

Abstract: *The preservation and enhancement of the urban landscape and its environmental and anthropological context , in areas such as the unique oasis cities, is a necessary prerequisite to transmit to future generations a unique heritage. Their extraordinary peculiarities arise by the interaction among culture, skills, experience, "know how" and the land that has shaped urban forms and landscapes as original, as exceptional for their uniqueness. The strategies of sustainable development must be understood here not simply as protection and preservation of goods and resources, but as an action based on a process of ecological and economic revitalization, where the increase in value of the resources and their organization in a system, may be the key for new attractions and socio- economic revival. The different interactions among the social, ecological and economic aspects indicate that these processes of exploitation/regeneration start from punctual intervention to overall development strategy, assuming the role of a key strategy to bring quality and identity to contexts of great value.*

Keywords: *Heritage, Sustainable valorization, Oasis city, Landscape*

Introduction

Cultural resources-understood in their largest sense- have established themselves as one of the most important conditions for ensuring sustainable economic development in many contexts we can define unique, for environmental and social peculiarities that characterize them. The promotion of cultural heritage and environmental protection, as well as guaranteeing the quality of life of future generations also offer, in fact, real economic opportunities and significant incentives to local activities, respecting the peculiarities of the local cultures.

The preservation and enhancement of urban landscape and its environmental and anthropological context, in *unique ambits* such as oasis cities, is a necessary prerequisite, therefore, from different points of view, first of all, to transmit to future generations an heritage, in fact, unique, recognized at international level. Then, for the extraordinary peculiarities that characterize it, that is formed by the interaction among culture, skills, experience, *know-how* and the land that has shaped, over the centuries, urban forms and landscape in structures as original, as *exceptional* for their uniqueness. Furthermore, these urban forms, the oasis cities, represent an urban and environmental complex, closed and integrated, whose good functionality exists when there is balance between the different components that is, between the structural elements of the urban space and the places of "naturalness ": the desert, the springs, the crops.

The ecological-environmental balance is at the basis of the structural functioning, but also that social one of these contexts, in which the formal features and their specific identity characteristics, in relation to the place in which they arise, with particular reference to the land, the crops or the surrounding landscape, represent a complex but unitary structure, to the point to say that we are talking about a particular condition of *city-landscape*, where the landscape is not simply *nature*, but it is *culture/civilization*, it is history, work and harmony sedimented over the time, in places particularly difficult and breakable.

A particular form of *city-landscape*, in the sense of a *city/urban system* basically shaped by the landscape and its characteristic elements, in which the material of urban construction is the landscape, the environment that shapes it. A city, so, which makes geography the basic feature of its form, in which the built/the architecture presents itself as an expedient of mediation with the environment, often hostile, inhospitable to the most and therefore not as

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oppositional element, bacause of its being anthropogenic, artificial, but completely in synthesis and harmony with the nature of the places.
We are, thus, in presence of artificial settlements created by the human project and intelligence, but whose characteristics are perfectly comparable to real ecosystems in perfect equilibrium with the nature of the places: *an oasis is an human settlement that, in arid geographical conditions arid uses resources locally available to create an amplification of positive effects and determine a vital recess auto-sustainable and a fecund environment in contrast with the unfavorable surroundings*. These forms of settlement are an eloquent, as extraordinary type of human intervention that transforms the places without altering the nature and also the perfect management of the resources has fostered the development of a social and economic model based on the principles of *collection, preservation and reuse* perfectly balanced and shared: a model, so, of sustainable use of resources and territory.

Mediterranean heritage: knowledge, skills and sustainable models of development
The condition of uniqueness of such contexts related to the particular mode of settlement in the area is common to other Mediterranean cultures. Over the oasis cities in the desert of Tunisia, Morocco and Algeria, other examples of particular forms of settlement can also be cited, from Petra in Jordan, to urban centers built in the so-called Sicilian *Cave*, Sperlinga, Pantalica or along the Gravina as the Murgia Gravina, Castellaneta Ginosa, the best known example of Matera recognized for its uniqueness in the World Heritage List of UNESCO and called by ICOMOS *the best and most complete example of population in harmony with the ecosystem in a region of the Mediterranean basin.*
The interpretation and use of the territory that takes into account all the symbolic, cultural, economic and social factors, which, in their interaction, contribute to form the landscape, as a complex cultural product that is at the basis of arguments that tend to consider the space not only as a place of resources and social dynamics, but as the creator of the actions and practices that are displayed/set in the space.
In fact, these places are not only statement of a long tradition of urban planning and architecture developed through the techniques and local materials, but they offer a synthesis of various cultural contributions and different interests: they are a cultural heritage of considerable value for the history, the archeology and the anthropology; they are an important part of the architectural heritage; they are the evidence of the ability to adapt to difficult situations and scarce resources; they are the evidence of the know-how of the different Mediterranean populations within the habitat and space management; they are the symbols of a well-established local identity and finally a strong point for local development (heritage).
The common element of the close connection between urban/built and nature in every example, represents a form of *unique* built landscape; whether it was to shape it the stone/excavated rock, and when the constructive language is obtained by using the raw land, we are always in the conditions to prove the complete continuity/harmony, merging with the natural elements of the landscape. These contexts, therefore , are actually rare and exceptional examples of urban organisms and architectural structures that we should call today *eco sustainable*, but probably first sprung on an intuitive level, then on an handcrafted level from an attention and an adaptation to the environment, to the places and the available resources, which has intrinsically oriented this ability to transform these sites, without altering or upsetting the delicate environmental balances. The result of the examples given is, in fact, a perfect equilibrium between human needs and morphological features of the environment obtained without, of course, that any planning has been there or project pre-ordered, but rather

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a constant adaptation to the site in full respect for the host environment, a continuous evolution of compatible exploitation of natural existing resources and use of building materials taken from the site of settlement.
Environmental sustainability and development of responsible models in the design/ construction and planning/urban and regional organization are, therefore, recurrent and implicit themes, developed in these contexts, in which the unfavorable conditions and the limited availability of resources have caused the adoption of sustainable, economical and highly effective strategies, both for the city and dwellings construction and to create conditions of fertility of soils and water availability in areas known to be characterized by drought and lack of vegetation.
Knowledge and interpretation of these urban and territorial structures, therefore, cannot be limited only to the study of settlement forms and land use for the supply of resources. Of fundamental importance is the concept of sustainability declined and related not only to the the environmental context, but extended to the social, political, economic and cultural level. Social aspects and all that is related to the links/ties among the people of the community cannot be underestimated; social and physical relations are decisive for the quality of the sites as well as for the good management of resources, relations such as that one of neighbourhood, for example, which is not only identified with the common space in which household equipment are shared - the well from which to bring water, the place for washing clothes or the oven) - must be understood as a model of social life, made of solidarity, cohesion and cooperation.
The social organization in participatory management of land and resources, especially in these areas where survival is derived from the subtraction of fertile land to arid zones, or otherwise hostile, puts into practice the gained knowledge and shares the efforts for the supplying and the common management of resources in order to achieve or reach situations of balance between the exploitation of resources and their availability. A kind of social-cultural, economic and productive model, based on self-sufficiency and self-production, from which descends the complex and intricate organization of spaces allocated to the management of activities and resources. According to Silvio Marconi, oasis *is the first complete ecosystem, totally artificial, created by humanity in the course of its evolution and it is made up of four artificial parts, separate but integrated: a system of water collection, underground; a water distribution system, partly underground and partly superficial; a trees protection system, usually made of a palm grove, with the underlying crops, trees and vegetables; a settlement.*(Marconi S., Roma 2000)
In this context is integrated the interesting phenomenology between constructive and socio-anthropological connections, which have generated these places and that have maintained for centuries intact the physical structure and its operation, making them arrive today as a knowledge heritage to scholars and not, in their condition of uniqueness.

Sustainable settlement culture in the elements structuring the space and the places

The expression of sustainable characters in the settlement culture of these contexts is well expressed in all the elements structuring the urban and territorial space, in the relationship man/nature and in the role of community in the management of resources and land. The morpho-typological aspects that join these settlements take form by the concentration and compactness of the tissues and the urban structure, the development of housing on several levels, the coverage of paths. These particular features are related to settlement and structuring criteria obtained by the rational and sustainable use of land resource: using less land for the built it means to have more available for irrigated and cultivable areas used for

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agricultural production, unique or almost only, source of sustenance for the settled population. Moreover, the compactness of the system and of the urban fabrics, in which the open spaces, the vacant places, are reduced to limited and narrow paths, favors the defense by chemical extreme conditions, in addition to the smaller dispersion of water resources.
Even the construction technologies (adobe or pisé) that derive directly from the available materials and found in place (raw land, palm wood), appear to be perfectly suited to the achievement of environmental quality of dwellings, for the the high level of passive protection compared to the elevated day and night temperature range. So as well as the type of houses contributes to the quality of life in the accommodation: the court types, set next, devolope themselves over three levels , ground floor , first floor and terrace , overlooking the courtyard and having a unique relationship with the road through the entrance. The road is almost always covered by the upper floors of the houses; the only air and light valve is through the light-wells located in the joints of the streets tangle, intersections of routes or entrances of the houses, which also have the function of orienting the pedestrian in the maze of streets. This urban system allows an absolute functional autonomy and protection from the outside of the houses and at the same time, avoiding through the coverage of the streets the solar radiation on the walls of the houses, a good control of the heat and environmental conditions .
The *palmeraie*, large area planted with date palm, represents the generating element of the built , of the urban layout. Formed by trees and by an extensive network of canals that carries water to different crops -the extension of cultivable land that it is possible to obtain, depends on the ability of water collecting- is a very complex structure, because thanks to the shadow generated by the foliage of the palm trees, it is possible the woody and irrigation underlying plantation. His organization for levels or layers, in fact, allows, in addition to palm trees, to let grow fruit trees and in the upper lower legumes and vegetables. Even the arrangement of the vegetation - with its supply of humidity - and of the terracings is not random, but it is functional to the cultivation and to the protection of slopes. It follows from this that from the dimensional point of view, the larger is the palm, the larger is the built, the city. From the functional point of view, it represents or represented the main economic factor of supplying and sustenance for the inhabitants of these cities. The palm is therefore an integral part of this urban and territorial system, in fact, only in the shadow of the palm grove it is possible, in such climates, realize any kind of cultivation plantations, able to ensure survival.
This system with its spatial structure, represents, therefore, the space of a common heritage of ideas and lifestyles, a liveable environment and ecologically friendly, but at the same time it is the inheritance of unique urban forms. It is undeniable the importance of historical memory, but even the work and the action of man, as a producer of territory and knowledge, in the awareness that this *landscape* is made up of elements connected together by sets of discontinuous and disconnected parties acting in symbiosis influencing themselves. Then, retrieving the continuity with the past and the cultural identity of these places also means recovering that intangible heritage of traditional knowledge and erudition, which are the real capital on which is based the urban culture, which is the genius loci whose every place is guardian. The inherent potentialities in the recovery of knowledge, skills, techniques and traditional building systems , are now recognized on an international level, in 1999 UNESCO and ICSU (International Council for Science) have made their statement: *The system of traditional and local knowledge as dynamics expression of perception and understanding of the world can provide, and historically has provided, a valuable contribution to science and technology, and for this reason there is the need to preserve, protect, research and promote this cultural heritage and empirical knowledge .*

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Enlarging the disciplinary field of reference from the pure preservation of historic buildings to the revitalization of the urban and social-economic planning and to all that pertains to the system of knowledge, skills and traditional techniques is a very interesting opportunity of approach that is based on the belief that a more comprehensive program of development of the city-oasis must be, first of all, an instrument sensitive to local issues and sustainability of places. In a sustainability perspective aimed to achieve a balance of the dynamics that occur among the natural, socio- cultural, productive and economic landscape, and settlement system, traditional knowledge can, therefore, be a valuable reference vocabulary to which draw on, because historically established, culturally accepted, but also ecological and economic. And they may be a suitable impetus for reaching new and higher levels of well-being of the communities settled for innovative forms of protection and preservation of local identities, able to integrate with the different needs of development and enhancement.

Strategies for sustainable development

The phenomenology that has produced these unique urban contexts, which have kept, more or less, intact the uniqueness that characterizes them, suggests to research methods and techniques respectful of an urban structure characterized by environmental functions and quality landscapes that include also historical heritage. A correct approach promises to evaluate the overall context as a whole, in its historical and social aspect, as well as the geographic and environmental one. *Prerequisite for understanding the oasis system and address the problem of its preservation is not the separation of the spiritual heritage from the cognitive-material one: the oasis encompasses the complexity of a world, all under the responsibility of its inhabitants. The oasis settlements are the result of a delicate balance and interaction of complex factors in which each component - social, architectural, agricultural and environmental - is an inseparable element of the system. The society of oasis in transformation and evolution requires the introduction of appropriate levels of service and improvement of the conditions of life avoiding that these destroy the values inherent in the system. Just the lack of understanding of these values, the negation of the whole oasis universe, has led to interventions of modernization that, operated in a sectoral manner, have been inadequate or even harmful* (Laureano, 1995, p. 71).

The Oasis is therefore location for multiple relations, for historical evidence, it is the receptacle and sediment of urbanity, it is a vector of practices and cultural values that are layered over time, it is the carrier and vector of a spirit that resides there, and that is the same transmitted. Beyond the physical description that constitutes it, heritage is the bearer and witness of elements that go beyond its simple materiality and the promotion and protection should not, therefore, limit to the restoration of physical assets, but must consider the architectural and knowledge heritage in order to make the oasis ecosystem a space of cultural and environmental development. The identity value of the cultural heritage is thus intended also as a possible vehicle for social cohesion , in order to build a large consensus around the objectives of sustainable development in the logic that:

- the only ambit of safeguard can not support the cost that it is required, that is not economically sustainable;
- the recovery should follow the methods of careful preservation of traditional building techniques, that, in addition to being themselves a source of cultural identity, are the reason for the survival of the oasis nowaday;
- *correct* reuse of places and functions can initiate broader sustainable development programs.

This approach declines, so, the concept of sustainability globally understood: environmental sustainability, social sustainability and economic sustainability, as it relates not only to the

protection of the environment , which also includes the urban, historical and cultural heritage of the places, but also to the defense of local identities and, above all, the social acceptability of the intervention projects on the territory.
Strategies for *sustainable development* in these areas must be understood, then, not as a simple protection and preservation of assets and resources, but as an action based on a more general process of ecological and economic revitalization, in which the value of resources and their organization in system, can be the key to generate new attractions and, therefore, socio-economic relaunch.
The different interactions among the social, ecological and economic aspects indicate that these processes of exploitation/regeneration go from punctual intervention to overall development strategy, assuming the role of a key strategy to bring quality and identity in contexts of value and unique; an extraordinary opportunity to meet the challenges of socio-economic transformations underway.
The challenge to receive is that to move from one empirical knowledge in the management and use of these sites to a planned , scheduled , but respectful of tradition awareness. The term tradition must not falsely led to think that it is a nostalgic reminder of the past. The etymology of the word itself, in this case, helps to understand the word; the term *tradere* in Latin means deliver, transmit. The transmission of knowledge does not remain fixed in time, but it turns adapting to the territorial changes and to the changing needs of those ones who inherit them. (P. Laureano , 2001)
Recognizing, so, in the protection of the identity and the transmission of knowledge that has contributed to determine the particular characteristics and uniqueness of a territory, an important factor of sustainability, it outlines a line of thought that while it recognizes the importance of environmental problem, on the other hand, it takes the distance from *endogenous models imposed* in the name of a presumed being ecological, which are not expression of culture and local knowledge; it flows in the direction of an approach that tends to bring to a local dimension the complexity of the problem, stating the importance of local identity and community participation.

References

Fathy H., *Architectur for the poor*, trad. italiana “*Costruire con la gente”*, Jacabook 1986
Fathy H., *La casa araba nell'ambiente urbano: passato, presente e futuro*, in Casabella 680/2000
Germanà M. L. e Panvini R. (a cura di*), La Terra Cruda nelle costruzioni. Dalle testimonianze archeologiche all'architettura sostenibile*, Atti della Giornata di studi 2007, Collana Politecnico Mediterraneo, Nuova Ipsa editore, Palermo 2008
Latouche S., *La scommessa della decrescita*,ed. Feltrinelli, Milano 2007
Laureano P., *Giardini di Pietra*, ed. Bollati Boringheri, Torino 1993
Laureno P., *La piramide rovesciata. Il modello dell'oasi per il pianeta Terra*, ed. Bollati Boringheri, Torino 1995
Magnaghi A. (a cura di*), Il patrimonio territoriale. Un codice genetico per lo sviluppo locale autosostenibile* in Rappresentare i luoghi. Metodi e tecniche,Firenze, Alinea 1998
Marconi S, *Il Giardino – Paradiso*, Linea Editoriale “i Versanti”, Roma 2000
Moretti G., *La Casa di Hatra. Uso delle risorse ambientali e climatiche nella tradizione abitativa mediterranea*, Ed. Tipoarte,Ozzano Emilia (Bologna) 2005
Perlin J. e Butti K., *Case e città solari del Mediterraneo antico*, in Sapere, Ottobre 2006
Pulselli R.M., Tiezzi E., *Città fuori dal caos. La sostenibilità dei sistemi urbani*, Roma 2008

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Think different – gain more, spend less
A real life example from a passive house refit

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Abstract: *In Alingsås, Sweden, the municipality´s public housing company Alingsåshem got to think outside the box while planning the retrofit of the residential area of Brogården. This resulted in a successful procured partnership with the contractor Skanska, working together, continuously improving the concept while transforming buildings from the 1970s to highly accessible modern apartments using passive house techniques. The low energy targets were met, yet the original positive character and spirit of the neighbourhood was preserved.*

We would like to share our experiences and inspire others to embark on a large scale energy efficient retrofitting. The example shows how the model using procured partnership and involvement enabled the development and use of innovative techniques. Some typical difficulties and success stories concerning energy retrofitting are presented, showing the path towards increased efficiency and rationalization of the construction process.

Holistic approach, Energy efficiency, Retrofitting, Procured partnership

Introduction

In order to address the energy use, the existing building stock is a key priority. Although an increasing number of high profile low energy buildings and passive houses have been erected in Sweden in recent years, there is still a clear demand for more energy-efficient refurbishments and new-builds. The reason for the slow development is most probably that these kinds of ventures still tend to be pilot-projects and as such they are considerably more expensive, and complex, than traditional projects.

In the Brogården project we have managed to reduce the energy demand for space heating by 75%, while ensuring a financial feasability. A holistic approach and active involvement enabled the development and use of innovative techniques. By this real life example of energy-efficient retrofitting we would like to share our methodology to others that are about to embark a large scale energy efficient retrofitting. Brogården is also one of three show cases in the EU funded BEEM-UP demonstration project to support further energy efficient refits.

Background – The Swedish context

Since the end of WWII, the standard of Swedish dwellings has been continuously improving. An important phase was the politically initiated "Million Homes Program" executed between 1965 and 1974. Large amounts of dwellings with modern standards for bathrooms, kitchens and HVAC systems were built in ten years, thus enabling better living standards for all

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members of society. The program resulted in 1,000,000 modern dwellings being built for a population of 7.5 million. As by now many of these buildings have reached a point where they are in immediate need of repair this is the time to address both the defects and to enhance the performance of the buildings. In addition to this, the large complexes with repetitive architecture are not currently considered “attractive” by the Swedish population.

The Million Homes were built in an industrial and repetitive manner. As we will show here, the key to renovating them will be to replicate that: to do it industrially and repetitively.

Public housing in Sweden

In contrast to other countries in Europe, Swedish housing companies provide *public housing*, not *social housing*. A large portion of the population, from all social strata, lives in dwellings provided by the municipalities’ housing companies. The public purpose of those companies poses demands and ethical, environmental and social responsibilities, often to contribute to a sustainable development and efforts to meet the climate challenge.

A substantial part of the houses built during the Million Homes Program is currently owned by public housing companies. These buildings are parts of a complex problem: beside the need for renovation, increased energy efficiency and an update to meet modern demands on comfort. Demographically, many tenants are economically vulnerable. Housing companies are thus faced with a situation where a launch of major renovations works is required while the rents cannot be increased to cover the costs. New strategies are therefore urgently needed.

Energy and building standards

The Swedish building code during the Million Homes Program-era, BABS 67, states an energy standard equivalent with U-values for floor, wall, roof of 0.40 W/m²/K and windows 2.7 W/m²/K (excl thermal bridges). For a typical apartment in Brogården, the ventilation rate should be approximately 0.5 l/s/m² floor area.

The current building code, BBR20, sets the building standard for an energy demand of 90-130 kWh/m²/a heated floor area for non-electrically heated dwellings and an average heat transmission coefficient of the building envelope (incl thermal bridges) of 0.40 W/m²/K for new buildings. The minimum air exchange rate in occupied dwellings is 0.35 l/s/m² floor area. Although the indoor temperature in dwellings is recommended to +20°C, the real estimated mean temperature is about +22°C [1].

Brogården

The residential area Brogården was built in1971-1973. It comprises 16 houses (3-4 stories high) with a total of 299 flats – all with their own indented balcony or patio. As a typical example of the Million Homes Program - there are thousands of houses in Sweden built with the very same blueprint - Brogården is listed as an area of cultural interest.

The houses in Brogården had poor indoor climate and great energy demand due to major thermal bridges, poor air tightness and insulation combined with insufficient indoor air

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quality. Surfaces were worn down, the flats had poor accessibility and the size of flats did not meet modern demands.

Brogården – the refurbishment

All measures needed in Brogården were planned to be coordinated and done in harmony with each other. The houses were stripped down to the concrete skeleton, and then rebuilt using passive house standards. The entire area also got high accessibility both indoors and outdoors. The refurbishment started in 2007 and finishes in September 2014. Work has been done methodically from one end of the area to the other, starting with a pilot house. Evaluations have been made after each finished house.

Figure 1: Brogården façades, balconies and entrances before and after retrofit. Photo: AB Alingsåshem

The tenants have been evacuated during the refurbishment. As houses are finished, tenants have moved back – meaning that evacuated houses, buildings with ongoing construction works and houses with tenants have stood alongside each other. For 299 households this refurbishment has made a notable impact on their daily lives for several years. Still, surveys show that they are happier with their homes now than before the works began.

Brogården – the energy savings

Through the implementation of passive house technology, focusing on high energy performance at good indoor climate conditions, the energy demand of the Brogården area has been significantly reduced. The technology focuses on a high thermal insulation rate and minimisation of thermal bridges, high air tightness in the building envelope and mechanical ventilation with efficient heat recovery (HRV).

An extensive monitoring programme within BEEM-UP in one of the buildings enabled further trimming of the energy performance through the HVAC systems, making full use of the heat recovery. Preliminary results for the first year, partly made before the HVAC adjustments, show that the energy demand for space heating has been reduced by 75%, see Table 1.

Before the refurbishment heating, hot water and household electricity were included in the rent. This most probably led to a negligent attitude towards energy savings. After

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refurbishment, heating is largely superfluous and hot water and household electricity are charged individually based on consumption. Economically this has lead to noticeable savings for the housing company and a considerable decrease in the tenants' consumption: Alingsåshem has noted a 20% decrease since the introduction of individual billing.

*Table 1: Preliminary results of energy use before and after retrofit of building H in Brogården [2]. Before retrofit, common and household electricity were not measured separately, thus the separation is an assumption. *Heating degree day adjusted values. ** Area = A_{temp}, Σ interior area of space heated to >10°C.*

House H (kWh/m²,year **)	Baseline period 2007 -2008	Reporting period 2013
Heating*	142	35
Domestic hot water	27	22
Domestic electricity	30	31
Common electricity	18	9
TOTAL	**217**	**97**
Mean indoor temperature	Not known	+22 °C

A holistic perspective – the key to success

Through the retrofit, the Brogården buildings have been granted a new, sustainable life. The process itself created valuable experiences and increased knowledge for all members of the team, from skilled workers to designers and decision makers. What makes this project different from many other retrofits, and what makes it a success, is the holistic approach. To us 'holistic' means a mindset where you take care to see the project and related aspects as a united whole. It has enabled us to think of the ecological, social and economical factors and their interdependence all at once. Through this approach we have gained added values to more aspects of our work, and this in a more efficient and cost effective way than achievable through traditional methods.

Take for example the decision to keep the the buildings' concrete structures, instead of tearing them down and build new ones:

- This had ecological benefits, since transportation, new outtakes of mineral resources and disposal of old concrete in landfills was not needed.
- This had economical benefits, since we did not have to dismantle the old structures, decontaminate the grounds and buy and erect new concrete frames.
- This had social benefits, since the listed area kept its layout and the residents had the comfort of knowing that well-loved homes would still be there for years to come.

What we have learned is that aspects of a renovation on this scale are not just lists of separate cases, but circles that overlap. We will highlight this through the key factors "long term perspective", "dialogue and involvement" and "challenges and lessons learnt".

The long term perspective

Brogården is the home of many people, whom must be treated with respect and provided a sustainable living environment. The buildings and the neighbourhood are our long term commitment. The buildings in Brogården are planned to serve for another 50 years, at least, after retrofit. Hence, conventional financial models cannot be applied as they do not comprise

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the whole life span of the buildings and tend to narrow the economy to the conventional running and renting of apartments.

Through a retrofitting with a long term perspective, the society benefits from a neighbourhood development that includes accessibility, home care service, shared facilities etc. The benefits might not always be easy to quantify, but even when conservative calculations are used the advantages are clear. By using the real time scale, solutions with low life cycle costs can be found even though they are more expensive initially.

The watchwords of the development have been to keep the quality and the soul of the neighbourhood while addressing technical defects. Several different scenarios were studied over time before deciding on a strategy, e.g. *As is, Replacement* and *Retrofitting to passive house standard*s. The *As is* alternative actually comprises quite a lot of maintenance costs in order to maintain an acceptable living environment, making Brogården a losing business in 15 years time. Looking at the alternatives it was given that the passive house retrofitting scenario will be the most profitable in approximately 10 years [3].

A large part of this can be attributed to the fact that future financial risks are reduced, as costs for operation and maintenance will be significantly lower after retrofitting. There is also a transaction of future behaviour-related risks of energy costs from the building owner to the tenant. The improvement of quality of the buildings and of the neighbourhood will also minimize future financial risks such as vacancies.

Dialogue and involvement

Procured partnership has been a key to success at Brogården. Thanks to this cooperation model everyone involved have been important cogs in the development process: designers, contractors, property managers and residents.

The partnership is a structured and modern form of collaboration where partners form the project together. The expected benefits are production and cost efficiency and continuous improvement of products and service. The partnership is characterized by trust, transparency, shared goals and dedicated partners. In a procured partnership all skills are seen as valuable. Focus moves from contract management to common solutions. A common and open budget, and in Brogården’s case even open accounting, is a precondition for a procured partnership. The profit of the contractor is a fixed amount, and every added costs or savings are split equally between building owner and contractor, thus also sharing the incentive.

Each stage of the project has started with an experience recuperation meeting involving every team member on the project. Continuous feedback-loops and evaluations from everyone involved have ensured working conditions and technical solutions to evolve during the project. An example is the evolution of the exterior passive house wall, which has been improved several times in terms of cost and time efficiency, ergonomics, logistics and technical performance. Many of these changes have been initiated by the skilled workers and carried out by the team. The urge for the carpenters to decrease heavy elements of work that

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cause stress injuries to elbows and arms resulted in not just 8000 screws less per building but also a quicker and therefore less expensive assembling process. As the structural engineer in cooperation with the framework steel supplier found new ways to connect the frame, the thermal performance of the wall was likewise improved.

Thanks to constant monitoring of the buildings' performances we know for a fact that the solutions chosen are as effective as intended – both regarding indoor climate and reduction in energy demand. The monitoring has also helped us to spot weak points in the construction and ventilation system and amend them before they become a problem.

The project involved a great number of tenants for a prolonged period of time. In order to create security, dismiss rumours and get feedback a continuous dialogue was established with the tenants. It is also much easier to create an understanding for changes made if the recipient has been involved in the early stages of the process. In addition to one-to-one meetings, all tenants have been invited to frequent open houses in a showroom apartment; we have published a newsletter and been available for all sorts of questions. All these actions have been made in collaboration between the housing owner Alingsåshem, the contractor Skanska and the Swedish Union of Tenants.

Through this dialogue we became aware of small but important things, for example that the tenants appreciated their yards but wanted more benches and tables – something that we could easily provide and thus getting a more satisfied costumer.

Experience feedback and lessons learnt
The large scale repetition in the design of the Brogården area has enhanced the possibilities of continuous evaluation and improvement. The high involvement and shared objectives have set every project member on the track to evaluate, learn and improve along the way. With every new building a new iteration has been made, enabling the project as a whole to further improvements of the organisation as well as of technical measures. Hereby, the industrial and repetitive design of the Million homes programme has supported a rational method of work, where the process can be refined along the way while making use of the experiences from each step to the next, building knowledge continuously.

Eg, the evolution of the wall system did not stop with the satisfying result from the first dia-logue. Within the BEEM-UP project in 2011, an interdisciplinary team was formed to further develop the wall system towards prefabrication, keeping the same technical performance. Through experience feedback, several mock-ups and tests, a prefabricated wall system has been developed for the three last buildings of the project, as a final answer to the thesis to retrofit these buildings in the same industrial way as they once were built.

Incorporation of old balconies in new dwellings A turning point of the design process was the decision to change the indented balconies to exterior ones, incorporating old balcony area in the apartment. It was a challenge to keep the buildings' expression without adding any extra load to the slimmed concrete frames, still supporting an efficient construction process on site.

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The result added extra value not just in terms of energy performance, where a major thermal bridge was cut and passive house performance made possible, but also to the tenants who were given a larger balcony. The building owner gains about 8m² of rentable space per flat, used to enlarge the bathrooms, thus meeting the demands of accessibility and standards of the 21st century.

Accessibility has been a core issue of the Brogården retrofit. With 60% fully accessible flats, social and economic sustainability is granted when tenants can stay in their home through all stages of their lives, significantly reducing public costs for care. Simple solutions can integrate accessibility for all tenants in normal flats. The original inset entrances have been opened and lit up, enhancing guidance for those with poor eyesight while increasing the sense of security for everyone. A lower position of entryphones, hooks and installations enable usage not only from a wheel chair, but also for children. The removal of excessive steps, introduction of seats and extension of handrails improve accessibility for everyone.

The elevator challenge In order to grant access to flats on all floors, highly energy efficient elevators have been introduced in Brogården. The elevators themselves show a great performance thanks to low energy machinery, LED lighting and stand by mode. The key point has been to effectively introduce the elevators in the existing buildings. Space for shafts was found in the layout, but since the listing of the area did not comply with exterior machine rooms on the roof, elevator pits were used initially. However, depending on the building's foundation the pit could not always be made as deep as desired, resulting in high costs for elevator machinery and/or concrete works. Thus, the permission to extend the shaft through the exterior roofs for the last buildings was the final key to the elevator challenge, solving one of very few issues that were not solved through project dialogue, long term perspective, experience feedback and continuous improvement.

Conclusions

The challenges posed to us at Brogården are not unique – nor are the houses. Building owners both in Sweden and in Europe at large are facing the same issuses. What is unique is our way to meet those challenges: we decided to handle the area as a unit, not as separate parts, and we decided to do it in collaboration with different kinds of competences. That holistic approach has meant higher costs initially but will pay back in the long run.

Even though Brogården is unique now, we hope that this approach has inspired others and paved the way for followers. Perhaps some day "thinking outside the box" will be the standard approach in energy-efficient retrofitting.

References

[1] Boverket (2010) *Teknisk status i den svenska bebyggelsen,* Karlskrona, Boverket.
[2] Gervind, P. (2014) Preliminary results from BEEM-UP WP3, to be published
[3] Alingsåshem, Skanska, SP (2013) *Brogården – med fokus på framtiden* Available: www.alingsashem.se/uploads/pdf/Brogarden_mars13_webbx.pdf, 2014-07-28

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Comparing socio-technical regimes and transition potential in Austrian and Swedish multi-residential housing

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Abstract: *Many countries in Europe face large-scale renovation of 20th century housing. Although challenges for energy efficient renovation are similar in many countries contextual differences create varying possibilities and barriers for actions. We present a comparative study of managerial practices regarding refurbishment of housing in Austria and Sweden, countries with large stocks of publicly built, owned and managed housing. Due to what we have identified as socio-technical traditions of the welfare state, rather distinct renovation strategies are applied. We conclude that a more reflective approach to refurbishment that coordinates policy for housing and sustainability with detailed knowledge of the stock and its socio-technical context is a way forward.*

Keywords: Energy efficient renovation, public housing, welfare regimes

1. Introduction

Large-scale up-take of successful technologies for energy efficient refurbishment is often inhibited by high costs for investments that is not always justified by reduced operational costs or increased willingness to pay among tenants. Furthermore, existing social, cultural, and architectural values of are often in conflict with energy efficient refurbishment [1] [2]. The aim of this paper is to build a framework to understand contemporary managerial strategies for energy efficient housing renovation and how these are shaped by contextual factors. In order to initiate a shift to low carbon and energy efficient refurbishment policy, the stakeholders need an understanding of the welfare state traditions in the housing sector. We compare housing refurbishment in Austria and Sweden, countries that both have large stock of housing originating in welfare regimes and which up to date is mainly publicly owned and managed. Our analysis relies on descriptions of the sectors and case studies (based on interviews and documentation) focusing multi-residential building in metropolitan areas. We describe the institutional regimes in 20th century housing by using Esping-Andersen's models of welfare state typologies [3] as well as adaptations of these typologies for the housing sector [4], [5] and [6] These institutions can both promote as well as inhibit sustainable transformation of housing, yet no research is available on the correlation.

2. Austrian public housing, welfare state type and cases

Austria's social state system can be classified as the corporatist-conservative type of welfare state regime, with a high degree of wage regulation and strong involvement of associations in policy regulation and implementation [6]. The majority of the social housing stock was built in the post war era and is still owned by limited profit housing corporations and municipal housing companies. The state of Vienna owns and operates a large share of pre-war municipal stock (Red Vienna). Matznetter [6] classifies the multi-family housing provision as an essentially corporatist network, which is partly open to commercial developers.

The municipal housing in Vienna has some specific features. The part of stock, built in-between wars, has low standards (no central heating or ensuite bathrooms). Due to lack of periodic maintenance, the tenants were encouraged to improve their apartment by installing bathrooms, heating systems and replace original windows. The municipality even granted subsidies and low interest loans for these tenant interventions. This resulted in non-homogenous standard of conversions and interventions. In the course of official refurbishment programmes, the city of Vienna follows a policy of "gentle urban renewal" ("Sanfte Stadterneuerung") based on renovations where tenants principally stay in their apartments in order to preserve social diversity and prevent displacement.

Unlike other European countries (Germany, Netherlands, etc.) the provision of social housing and state subsidies are still part of the official housing policy. Gradually, since the 1970s, sustainability measures were integrated into the existing subsidy system, with medium to high standards of energy efficiency. There is a strong bias towards new construction and lower standards in refurbishment. The Austrian Federation of Limited-Profit Housing Associations, one of the most powerful actors in the corporatist network, recently questioned the cost-effectiveness of energy efficiency measures and future national sustainability plan. The federation concluded from an empirical study of 321 buildings and 14.220 apartments that housing affordability is more important than energy efficiency measures. The Austrian national sustainability plan, which foresees complete refurbishments of building skin and heating system, should be revised in favour of gradual, partial refurbishments. Due to the mechanisms of the corporatist welfare regime, this approach will very likely provoke changes in future governmental policy.

The Austrian cases comprise a municipal building from the Red Vienna era (1918-1934) and a refurbished facility of privatized, former non-profit housing association of the post-war era.

2.1. Red Vienna, pre-war social housing in Vienna

The stock of Red Vienna counts 65.000 housing units in 382 buildings and is a protected historic monument. The stock is managed by the municipal housing association Wiener Wohnen, one of the worldwide largest property management organizations, with 220.000 housing units in the portfolio. The buildings of Red Vienna have an insufficient state of repair and apartments are inappropriate to modern demand considering size of housing units and facilities. The case building, Elderschhof, is a block completed in 1932 with 125 apartments in 5 storeys and public spaces for rent in the ground level. The building was refurbished in 1952 (attic conversion), elevators were installed in 1966 and 1973, and modernized in 2006. The building underwent an extensive thermal refurbishment 2012-2013 (roof and façade insulation, changed windows) aiming for a 66% reduction of heating demand [7]. The refurbishment was carried in a completely occupied state. According to the planning documentation, 39% of the apartments have undergone a modernization (42 documented apartments). These measurement further included installation of a bathroom (which was not a part of the original fitting, only sanitary cell for every apartment), acoustic insulation, and conversion from gas heating for district heating.

2.2. Housing from the 1970s in the vicinity of Vienna

The second case is a housing development from 1977-1979 situated in a small municipal community in the vicinity of Vienna. The building was erected by a former non-profit housing association, which was founded by the state of Austria in 1950/51 to provide housing for public servants. The housing association was privatised in 2002 and through disposal to an investor-consortium. Today the association acts as a real estate developer and asset manager, managing over 37.000 apartments. The specific housing development has undergone a refurbishment after the privatization, in the course of long planning process starting in 2006, and construction in 2011. The facility consists of three attached blocks with 24 housing units. Within the refurbishment process six apartments were added on top of the attic and the parcel was densified with a new block with 13 dwellings. Elevators were installed to ensure accessibility. The building was refurbished to the passive house standard, through additional insulation, new windows, conversion of balconies into conservatories, and installation of a ventilation system. A biomass system and solar collectors were installed as a substitute to the former electro heating. The building was refurbished in inhabited state (four stacked apartments simultaneously in a three week period), where the involved tenants took vacation or moved to an empty apartment in the building for the three weeks. In an intensive participation process, where each apartment was visited by the planner and the housing association's representative in order to document the state of the apartment and the wishes and worries of the tenants. A workshop with tenants also preceded the refurbishment process. The refurbishment was enabled through a federal subsidy enabling social (accessibility, reduction of household costs for heating/hot water, and comfort), economic (creation of additional rental space) and ecologic (CO_2 reduction, renewables) sustainability.

3. Swedish public housing

Swedish public housing is owned and managed by municipal housing companies. They own almost 30% of the total share of multi-residential building nationally (750.000 apartments). In the 1930s a large political programme for 'good housing' for all inhabitants was established and implemented on a large scale after WWII. The social democratic government saw municipal housing companies as a way to provide decent and affordable housing for all types of households [5]. Housing built in the 1940s-50s is characterised by care for the user in design from landscape down to layout of the individual apartment, and care in material choice and detailing. It was constructed by handicraft methods and has been called the 'golden age' of 20th century Swedish architecture. In order to resolve the pertaining shortage of housing, industrial construction methods were introduced and a 'million homes programme' which saw the one million new homes erected in merely 10 years, some in new suburban satellite areas.

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Towards the end of that programme housing needs became saturated, apartments remained empty and many suburban areas entered an enduring period of stigmatisation. The social housing programme was constructed with generous loans linked to standard requirements (central heating, bathrooms, kitchen etc.). Loans were granted to private and public developers with slightly better conditions for the public. Sweden decided not to install a social housing programme that would have divided the housing stock in different quality categories. Instead housing subventions are provided to individuals, which are able to choose on the housing market. During an economic regression in the 1970-80s there was for a time loans available for energy efficient renovation. In the beginning of 1990s state subventions for housing construction were abolished as well as loans for renovation. Today, Swedish public housing companies act on the same commercial basis as their private competitors [6]. Since several decades the post-war housing stock has been in focus for actions to counteract social and later on technical depletion. An important institution in the rental housing market is the National Tenant's Union. Public sector rents are set in a system of collective rent negotiations between municipal housing companies and the local tenants' union [6]. A recent proposal for a National Strategy for Energy-Efficient Renovation does not take social or cultural effects of an increased renovation rate into consideration.

The Swedish cases comprise two municipally owned buildings and one facility of a privatized, former municipally owned area, all located in the region of Gothenburg.

3.1. Backa Röd – transformation of 1970s block into passive housing in Gothenburg

Poseidon, the largest and wealthiest of four municipal housing companies in Gothenburg, was ones client and builder of many districts they own and manage today. In the 1990s, they carried out some 'turn-around' renovations of post-war housing with support of large subsidies. As part of the on-going debate on energy efficiency, Poseidon initiated a pilot project in 2009 in which they heavily transformed a 1970s four-storey tower block to low energy (~60% energy reduction). Adjacent three level lamellar buildings are renovated in a light version without upgrading of the building envelope. At the start, the tower was almost vacant and after the relocation a few of the original families moved back. Due to the low attractiveness of the area, the low ability to pay among tenants, and low energy prices, the energy efficient renovation is a negative economic affair. In a planned future renovation of the district, two storeys will be added on top of the existing towers aiming for higher income tenants in order to change energy efficient renovation into a positive economic affair.

3.2. Pennygången – renovation of privately owned stock from the 1960s in Gothenburg

Pennygången, the first experimental area with industrialised methods in Gothenburg, built by a municipal housing company to last 20 years, is today in urgent need for technical upgrading. The area consists of four storey lamellar buildings with mainly larger apartments. The tenants, many families with children, benefit from low rents but complain about lacking maintenance especially regarding plumbing. The area is rather centrally located and not especially burdened with social problems. In the 1990s the area was traded by the city to a large building contractor who promised to renovate the area. This was never fulfilled, only the roofs and windows were changed, and the area was sold to another company, which in turn was bought by the present private property developer. The developer has decided to make a refurbishment to pro-long the building life-time with 50 years. The refurbishment includes measures for energy efficiency, noise reduction and increased comfort levels thus raising standards and rents. The owner considers the interventions to be a minimum to which no deviations can be made. The expected rent increase of about 60% has met strong opposition among tenants who brought the case to tribunal but lost. The opposition has attracted large media attention and created a negative image of how the owner deals with the process without a tenant dialogue. Due to the tenants' opposition, the process has been delayed and a tenant dialogue has been initiated. Similar refurbishment cases with large rent increases are found around the country.

3.3. Säteriet renovation of housing from the 1970s in Mölndal, vicinity of Gothenburg

Säteriet is an area in an adjacent municipality to Gothenburg that has been burdened by bad reputation and vacancies. The municipal owner and manager created a holistic and long-term vision for the area in which they defined technical, economic, social and architectural goals to preserve the original facades and the 1970s design. The selection of the architect and all decisions has been taken with a basis in the vision. The renovation concerns mainly the exterior (facades and roofs), only minor changes were made to kitchens and bathrooms. The tenants did not need to relocate and as exterior work cannot directly be transferred to the rent, only minor rent increases were made. Parts of the façade were renovated and preserved and some parts were changed and insulated. Despite that no heat exchanger has been installed, a 35% energy reduction has been achieved. The tenants were invited to workshops to decide upon building parts that were changed. The area was nominated to a prestigious national prize for restoration, and is now fully rented having a 6-7 years queue for an apartment in the area.

4. Comparison of Austrian and Swedish strategies

Table 1. Comparison of welfare state regimes in Austria and Sweden and policy for refurbishment

	Austria	**Sweden**
Classification of the Welfare state regime [3]	conservative-corporatist	social democratic
Welfare state type in housing sector [4]	conservative-corporatist	conservative-corporatist
Rent market classification [4]	integrated rental market	integrated rental market
Policy for energy savings	National Sustainability plan major refurbishment to reach energy goals	Proposed national energy efficient refurbishment strategy, not in force
Subsidies for energy efficiency measures	provided for both commercial and non-profit developers	Not available (limited to housing for elderly)

Austrian energy efficiency measures in social housing are very ambitious. However, deeper consideration of users interests is necessary to ensure effective results of energy reduction measures and user acceptance, and allow for better integration of social aspects of sustainability, such as affordable rent policy and prevention of energy poverty. Predominantly corporatist nature of welfare state regime in Austria results in heavily subsidy dependant measures, as well as in paternalistic, top-down implementation. Sweden, on the other hand shows some of the specifics of the social democratic welfare stage type, particularly by a higher degree of tenant participation in decision-making.

Table 2. Comparison of approaches to housing refurbishment in studied cases

	Austrian cases	**Swedish cases**
Management strategy	Municipal housing association: Owner and manager, do not invest or develop new property.	Municipal housing companies are owners, managers and invest in new development of housing.
Economy	Non-profit, limited financial means, strictly regulated rent, highly dependent on subsidy	Act on commercial basis. Municipal owners in larger cities have a good economy, rents negotiated between Tenant's Association and property owners (private and public).
Vacancy	Almost zero. Average duration stay per housing unit is 40 years. Waiting list for municipal, social apartments is 4 years.	Larger cities have no vacancies and long waiting lists for rented housing (public and private). Vacancies have in the past been a reason for large interventions and costly refurbishment – this strategy seems to be continued although there are no vacancies.
Tenant participation	Limited, dialogues with little impact on refurbishment measures	Form of dialogue varies.
Refurbishment Strategy	Seldom large interventions for refurbishment, not always good knowledge about actual standard of heating, kitchen and bathrooms, refurbishment often in semi-inhabited state. Political decision, depending on availability of subsidy	Based on good knowledge about existing central heating systems and standard of equipment in kitchen/bathrooms. large refurbishment interventions lead to relocation of tenants. Some managers chose a lighter version of renovation.

5. Concluding remarks

Our case studies illustrates the conflicting objectives - social versus ecologic - in refurbishment of housing. Future large-scale refurbishment of housing stock but also managerial and planning practices in both countries are dependent on the role of corporatist welfare state institutions. In Austria non-profit housing associations still seem to take a social role standing up to the national value of affordability in public housing against national sustainability goals for energy-efficiency gain from the housing stock. The Swedish Government proposes energy efficiency through refurbishment of housing as a national strategy but gives no financial support as is done in Austria, instead costs are often passed onto tenants. The Pennygången case illustrates an on-going debate about the social effects of costly energy efficient renovation – a discourse is much driven by the Tenant's Association. There are no political ambitions to resolve this dilemma and the role of the Swedish municipal housing companies in a definanced housing sector is not clear.

This study points to different prerequisites for refurbishment strategies where the Austrian housing owners have to deal with a lack of knowledge of the state of their own housing stock which represents very diversified technical standards, as illustrated by the Red Vienna case, whereas the Swedish case owners have better overview of the standard of their stock, which is much more homogeneous, and thus choose to apply comparatively large interventions and at one occasion. Further research is needed to analyse whether non-profit housing associations are more likely to implement long term and large-scale sustainable transitions then commercially operating housing providers and which strategy for refurbishment is the most effective, a large total intervention as in the first two Swedish cases and the second Austrian case, or a partial, gradual change process as proposed by the third Swedish case and the Austrian Red Vienna case. Such analysis should be based on in-depth understanding of the historic formation, modus operandi and traditions of well-fare institutions and their influence on the sustainable transformation of 20th century housing. We conclude that the creation of common knowledge base concerning the state of the stock and the long-term impacts of refurbishment measurements as well as of participation platforms for negotiation of different interests are necessary in both countries.

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References

[1] Hassler, U. (2009). Long-term building stock survival and intergenerational management: the role of institutional regimes. *Building Research & Information,* 37:5-6, 552-568.

[2] Nicol, L.A. (2011). The role of institutional regimes in motivating change for sustainable housing. *Building Research & Information,* 39(5): 459-472, doi: 10.1080/09613218.2011.588590.

[3] Esping-Andersen, G. (1990). *The Three Worlds of Welfare Capitalism.* Cambridge: Polity Press.

[4] Kemeny, J. (2006). Corporatism and Housing Regimes. *Housing, Theory and Society,* 23(01): 1-18, doi: 10.1080/14036090500375423.

[5] Lennartz, C. (2011). Power Structures and Privatization across Integrated Rental Markets: Exploring the Cleavage between Typologies of Welfare Regimes and Housing Systems. *Housing, Theory and Society,* 28:4, 342-359, DOI: 10.1080/14036096.2011.562626.

[6] Matznetter, W. (2002). Social Housing Policy in a Conservative Welfare State: Austria as an Example. *Urban Studies,* 39(2): 265–282.

[7] Lorbek M., Kovacic I., Höflinger M (2013). Resource Conserving Renovation, Energieeffiziente, Ressourcen erhaltende und differenzierte Sanierung historischer europäischer Gebäudebestände, Leitfaden. *Berichte aus Energie- und Umweltforschung*, 20a.

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Managing sustainability aspects in renovation processes: interview study and outline of a process model

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Abstract: *In many European countries there are building stocks in need of extensive renovation. This constitutes an important opportunity to perform energy-saving measures and improve indoor environmental quality. In this paper we report results from interviews conducted with Swedish property owners aiming towards in-depth understanding about renovation processes. We present identified barriers which counteract proper handling of sustainability aspects throughout the renovation process. Examples of important barriers revealed in the interviews are; insufficient investigation of existing building, absence of general overarching objectives and guidelines, and lack of knowledge about sustainability aspects. In addition, interviews pointed at a need for supportive documents. Based on the results from the interviews, a process model is to be developed. In this paper an outline of the model is presented. The aim of the model is to promote better management of sustainability aspects throughout a renovation project.*

Property owner, renovation process, sustainability targets, process model, SME´s

1 Introduction

The apartment building stock in Europe is currently facing a vast renovation need. This need could be dealt with in many ways which will play an important role for the possibility to reduce future energy demand, climate change mitigation and to enhance indoor environmental quality. The Swedish Environmental Quality Objectives (EQO) (1) state a reduction of total energy use per unit heated area in the built environment by 50 % by year 2050 compared to the base line of 1995 (2). Similarly, such reduction targets are addressed by for instance the European Union (3) and IPCC. To reach such targets it is estimated that roughly two million Swedish dwellings need to be upgraded, the situation is similar in many European countries. In contrast to production of new buildings, far-reaching renovation projects focusing on reducing energy demand together with enhanced indoor environment are still mainly seen as pilot cases. Barriers for a broader implementation of renovation processes towards more sustainable buildings have been investigated by e.g. (4), (5) and (6). Except the fear of high investment cost and problems with profitability, key barriers identified in these studies include lack of knowledge of sustainability aspects, lack of simplified evaluation tools (for decision-making), and how to formulate adequate measurable environmental targets. Other barriers are insufficient knowledge of the buildings and coordination between energy-saving measures and maintenance. In this paper, we report results of an interview study aiming

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towards in-depth understanding about renovation processes of today and how sustainability aspects currently are handled by Swedish property owners. Based on this, a process model is outlined which aims at systematizing integration and effectively address energy, environmental, and indoor environmental aspects throughout the renovation process. We refer to this as *sustainable renovation*, well aware of the variety of definitions used in practice for this concept. This work is part of a Swedish R&D project called *Environmental management of renovation processes* led by KTH Royal Institute of Technology in cooperation with a group of stakeholders from the Swedish housing industry.

2 Method

Interviews were performed to get an overview, but also more of in-depth understanding of current integration of sustainability aspects in renovation projects of multifamily buildings. The interviews involved six different Swedish property owners and were to a high extent open-ended. The organizations were selected mainly due to them being part of the reference group of the project. Nevertheless, they represent three important categories of residential property owners which, in turn, represent a large amount of Swedish multi-family housing, the three categories are small private companies, larger public-owned companies and housing associations. Interviews were conducted during 2013 with organization representatives with environmental expertise or responsibility for environmental issues. In two of the organizations an additional interview was held with a person experienced in operative work of renovation projects. Interviews were recorded and lasted for about two hours. Seventy pre-defined questions, in eight different categories, were developed. Questions were established due to our perception of the lack of simplified methods, procedures, etc. to address sustainability aspects. All questions were sent out in advance and many of the questions left opportunities for deliberation between the respondents and the researchers during the interviews.

3 Interview results

In this section main interview results relating to the forthcoming process model development are summarized. Focus of this work is how to address sustainability aspects throughout a renovation project. However, it is necessary to know something about the evaluation of economic parameters and how these affect the decision-making process. The interviews display that there is none or very little funding reserved for renovation purpose regardless of whether it is a public or a private organization. Therefore each renovation project has to be funded by increased rents and/or reduced operation cost. Increased rent is negotiated between property owner and the Swedish Union of Tenants (7), owners of rental properties must receive at least half of tenants' consent before performing measures that will lead to increased rent (8). Another economic aspect that influences decisions of measures taken is the required return of investments. Some of the interviewed organizations have an overall required rate of return and some have a specific rate of return for each individual property. Based on the respondents' answers, the rate of return is typically 4 – 7 %. Most of the respondents use some kind of Life Cycle Costing (LCC) approach when estimating profitability, but a few use only simple pay-back time estimations. One problem identified is the lack of overarching guidelines regarding economic evaluation and what numbers to use. Even within the same organization different numbers for the same parameter e.g. annual increase in energy prices are used when calculating profitability. Often it is the project leader who determines what parameters to use which, means different evaluation of the same measure in similar projects.

Below follows interview findings of significance for the development of the process model.

3.1 Property management

General sustainability objectives within an organization could possibly work as support for also formulating sustainability requirements in renovation projects. The four large organizations have environmental management systems certified according to ISO 14 001 standard. Three of them also have overarching sustainability objectives related to renovation specifically. Regarding maintenance plans, three organizations work with more or less developed maintenance plans, but none of them includes sustainability objectives. The two smaller organizations do not have maintenance plans, but on the other hand the interviews revealed that due to them being small, the responsible persons have a good tacit knowledge about the status of the building stock. Monitoring and follow-up of energy usage in the property management process is an important starting point also for formulating adequate sustainability targets and selecting measures in a renovation process. All six organizations, except one, monitor energy usage in some way; however, analysis of the monitored data is more limited. Only one organization has regular reconciliations about energy usage together with the Energy Manager. None reports energy usage on a more detailed level than total energy use for heating and total electricity use for building operation. If domestic hot water is measured separately, this is also reported separately. Investigation of indoor environment is very limited in the studied organizations. All four larger organizations regularly use customer satisfaction inquiries, but only one of them includes a few questions about indoor environment. Apart from that, user dissatisfaction with indoor environment is only identified through the regular procedure for handling complaints.

3.2 Renovation process in general

When it comes to overarching sustainability objectives in renovation projects the picture is varying. Three organizations answered that they do not have any overarching targets at all. Of the three remaining organizations, which all are large, one answered that their goal is to reduce operation energy use with 50 %, and the other two with 20 %, when performing major renovations. Regarding the presence of current general models for managing sustainability aspects in renovation projects only one of the six studied organizations have what they call an "environmental description" (an overall guideline adjusted to each specific renovation project). In addition, another organization answered that they use the Swedish environmental rating tool Miljöbyggnad (9) as a steering tool. Among the respondents it is rare to establish environmental programs and plans; this is only done in extensive redevelopment projects. The interviews revealed that how these aspects will be addressed depends to a high extent on the dedication and skill of the project leader. However, the interviewed showed that the project leader is provided limited internal support on how and when to address sustainability aspects throughout a project. A more open question was also posed about how to promote better

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management of sustainability aspects throughout a renovation project; this resulted in the following suggestions:

- Disseminate knowledge on sustainability aspects to stakeholders such as project managers, consultants, contractors, tenants etc.
- Involve environmental expertise supporting the project leader with knowledge.
- Set up sustainability aspects as a recurrent point on the agenda in design team meetings etc., and introduce checklists to help the project leader to address them.
- Start using existing tools like Miljöbyggnad (Swedish environmental rating tool).

3.3 Investigation stage

Before starting a project most of the organizations stated that they perform a building investigation. However, this investigation is commonly done on a general level, either with own personnel or with consultants. In the studied organizations alternative measures (e.g. exchange of windows vs. renovating existing windows) are usually evaluated by LCC. We were also interested in their reasoning regarding environmental performance on a life cycle basis. Respondents were currently not considering e.g. embodied greenhouse gas emissions due to added materials when renovating but four organizations showed interest in this if there was a simple and accessible tool for the purpose. Considering tenants opinions about a forthcoming renovation is one issue that may affect the outcome, as well as their degree of satisfaction. The four larger organizations have some kind of tenant involvement process. Two organizations involve a “renovation coordinator” aiming at facilitating the communication with tenants throughout the process.

3.4 Construction stage

Two things that according to the interviews greatly seem to affect the level of integration of sustainability aspects in the renovation process are contract form, and skill and engagement of the project leader. Turnkey contract is the most used type of contract among studied organizations. Some have tried partnering contract, but only two use it regularly. There is an overall agreement among the respondents that if the partners in a partnering contract are engaged this will yield a better outcome. However, the main reason for using turnkey contract is that less personnel is needed from the property owner´s point of view. Interviews also display that the contractor will have a higher influence over the project, including sustainability aspects, in a turnkey contract compared with a partnering contract. This means that the outcome will greatly depend on the competence and engagement of the contractor if procurement documents are not professionally handling these aspects. Four organizations use internal project leaders and one of them have project leaders specialized in either new construction or renovation. Remaining two organizations, one small and one large, are only using consultants as project leaders; however, they try to use the same consultant to preserve experience for future projects. The skill and engagement of the project leader may differ depending on if internal or external project leaders are assigned to the project or if specialized in renovation projects.

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3.5 Follow up

Finally, sustainability targets ought to be followed up properly after renovation actions. The studied organizations perform a very limited follow-up. In general, only energy usage is monitored (e.g. monthly reading, without any detailed analysis). Follow-up of indoor environmental aspects does not exist, two of the organizations answered that they install temperature sensors in some apartments, but no other aspects are considered. However, most respondents expressed the importance of satisfied tenants.

4 Discussion

4.1 Conclusions from the interview study

From the interview study we can conclude some main differences between different types and sizes of organizations. Large companies and housing associations usually work with maintenance plans, small companies do not. On the other hand, the responsible person in a small company instead has a good tacit knowledge about the status of the building stock which, at least for very small companies like the ones in this study, compensates the lack of maintenance plans. Regarding monitoring energy usage there are no differences between organizations, analysis of energy usage are rare in all cases, but is clearly important for the future evaluation of renovation measures. Larger companies use customer satisfaction inquiries regularly, but they rarely include questions about indoor environment. Doing so could be an effective way to scan the tenants' opinions. Building investigation are used by most organizations, however, the investigations are often made on a general level without in-depth analysis of i.e. energy use or causes of indoor environmental problems. Small companies and housing organizations do not have overarching sustainability targets; this is more common in large companies. However, these targets tend to aim too low, one example is organizations that aims at the year 2020 target, buildings renovated in the coming years will not be renovated once more before 2050. Regardless of type and size of the organization it is unusually to set up environmental programs and plans; this is only occurring in extensive redevelopment projects done by large companies.

Table 2 summarizes key considerations or barriers which were identified through the interview study and need to be dealt with better in order to promote more sustainable renovation processes among Swedish residential property owners.

Table 2: Key considerations or barriers resulting from interviews.

Area of concern	Key considerations/barriers
Routines and processes	Lack of procedures, checklists etc. for managing sustainability aspects throughout a renovation project.
	Limited use of environmental programs (property owner's documentation) and environmental plans (contractor's documentation).
	Lack of energy, environmental or sustainability objectives in maintenance plans.
Competence of personnel	Skill and engagement of project leader may to a high extent affect how sustainability aspects are addressed throughout the project.
	Lack of environmental expertise supporting the project team throughout the whole process.
Environmental	Lack of detailed analysis or investigation of energy performance, which is important in early stages.

performance, energy usage	Follow-up is often very limited, both environmental improvements and energy usage are followed-up on a very general level.
Evaluation of measures	Large differences (even in the same organization) when evaluating measures in both economic and technical aspects.
	Lack of general overarching guidelines for input data such as annual increase in energy prices, service life of products, inflation etc.
	No consideration of embodied greenhouse gas emissions due to added materials.
Customer satisfaction inquiries	Inquiries are regularly used but they seldom include questions about indoor environmental quality.
	Non-existing in-depth inquiry to find problems with the indoor environment prior a renovation.

4.2 Outline of process model

Based on the presented in-depth interview study and studies of documents, a generic gross process model is developed to address known key considerations and barriers as the ones in *Table 2*. The whole model primarily targets smaller organizations and housing associations. The aim of the model is to promote better management of sustainability aspects throughout a renovation project. In the model, early stages and follow-up is focused since these are the stages that differ most from the process of new construction. To integrate management of sustainability aspects as early in the process as possible is also of key significance for a successful process. Key starting points for the model development include:

- The layout of the model should allow organizations, which do not have a regular renovation process description, to use this with a slight modification. If a property owner already has a renovation process description the model ought to serve as inspiration for integrating elements of significance that are currently not included.
- Provide suggestions on routines which reduce the risk of not considering sustainability aspects due to limited competence and interest of the project leader and/or contractor.
- Clearly state responsibility and competence requirements for different tasks and actions described in the process model.
- Provide applied checklists, links to already existing adequate and qualitative checklists and examples on for instance items for early investigations, environmental target formulations, environmental programs, etc. for direct hands-on application.
- Give suggestions on formulations and performance levels of key sustainability targets for renovation projects to assist in working with targets that steer towards EQO, international commitments, etc.
- Provide illustrative examples on how different steps in the model can be applied in practice.

Below, an example of one part of the process model is concretized, *investigation phase in early stage*. The process model will consist of motivating text divided in different levels, from general to specific information. Each level is then divided into different activities that could be taken in the addressed project stage. Furthermore, the text refers to appendices containing more detailed information, checklists, templates, and references to external sources, see example in *Figure 1*. In this way, e.g. a project leader can find some general information about activities to consider in each project stage. If the activity is relevant further information

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is to be found in the appendices; otherwise one can continue to the next activity and so on. The different activities in this example include technical investigation, thermal imaging, envelope leakage test, customer satisfaction inquiry, templates for analysis of energy use, etc. In the process model the reader is given recommendations of whom, or what competences that are necessary, to perform each task.

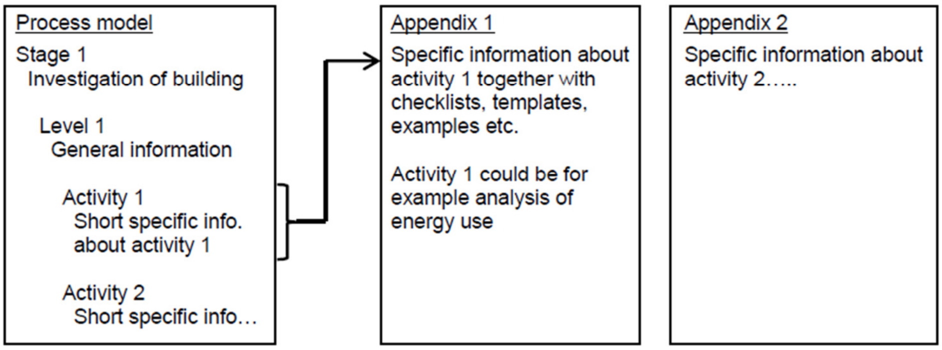

Figure 1: Schematic explanation of process model with more general text in different levels which refers to more detailed documentation, checklists etc. in appendices.

The present version of the process model is currently further developed in an iterative process in which comments and suggestions will be collected at a number of occasions from the reference group and other relevant stakeholders. Different stages of the model will also be tested in case studies in the interviewed organizations and be implemented as examples in the appendices. The model will recommend appropriate target levels for sustainability aspects.

References

1. Swedish Environmental Protection Agency. (2014) *Miljömålen – Årlig uppföljning av Sveriges miljökvalitetsmål och etappmål 2014*. Stockholm. Naturvårdsverket.
2. Swedish Government. (2006) *Regeringsproposition 2005/06:145*. Harpsund.
3. Economidou, M. et. al. (2011) *EUROPE'S BUILDINGS UNDER THE MICROSCOPE A country-by-country review of the energy performance of buildings*. Brussel. Buildings Performance Institute Europe (BPIE).
4. Thuvander et. al. (2012). Unveiling the Process of Sustainable Renovation. *Sustainability*, 4(6): 1188-1213, doi:10.3390/su4061188.
5. Häkkinen, T. and Belloni, K. (2011). Barriers and drivers for sustainable building. *Building Research & Information*, 39(3): 239-255, doi:10.1080/09613218.2011.561948.
6. Cattano, C. et. al. (2013). Potential Solutions to Common Barriers Experienced during the Delivery of Building Renovations for Improved Energy Performance: Literature Review and Case Study. *Journal of Architectural Engineering*, 19(3): 164-167, doi:10.1061/(ASCE)AE.1943-5568.0000126.
7. Högberg, L. et. al. (2009). Incentives for Improving Energy Efficiency When Renovating Large-Scale Housing Estates: A Case Study of the Swedish Million Homes Programme. *Sustainability*, 1(4): 1349-1365, doi:10.3390/su1041349.
8. Gregow, T. (2006) *Swedish Law Jordabalk (1970:994) 12 kap. 18d §*. Stockholm. Norstedts Juridik.

9. Malmqvist, T. et. al. (2011). A Swedish environmental rating tool for buildings. *Energy*, 36(4): 1893-1899, doi:10.1016/j.energy.2010.08.040.

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Session 15:

Which should the challenges of buildings rating tools be?

Chairperson:

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Tools comparison: ECÓMETRO vs existing environmental building assessment systems.

Abstract: *The economical and environmental problems due to unsustainable development, point the attention on the need to reorient the growth towards environmental improvement, wellbeing and social equity. The construction plays a strategic role, because is one sector where few actions for reduce its impact are been taken. In this context, the environmental assessment systems can contribute as framework to support a change toward a more sustainable growth model.*

Between several existent assessment systems, ECÓMETRO is a tool born as response to different ecological questions involved in the buildings design and construction process. The tool is being developed according to Life Cycle Analysis methodology and open source approach. The development work is based on community knowledge sharing and ongoing update and improvement by the same community.

The comparison between existing tools is the first step to understand strengths and weakness of assessment systems in order to improve the best solutions for ECÓMETRO. This work has been realized through an open workshop where experts of building environmental assessment systems have brought them extensive knowledge about the theme. The systems evaluated are LEED, Passivhause, VERDE and ECÓMETRO. This document shows the comparison result that can be very useful to guide the designer between different evaluation system options.

Key words: Environmental Building Assessment, Green Building, Sustainable Architecture, collaborative project

Introduction

The climate change is a reality, and the recognition of the CO2 emission due to anthropogenic activity as the first responsible puts the energy efficiency, the emissions reduction and environmental protection as the main challenge of twenty-one century society.

The construction industry is a large contributor to CO2 emissions: the buildings are responsible for 40% of the total European energy consumption and a third part of the CO2 emissions. The concept of LCA applied to construction underlines the direct relation between buildings and resources consumption in the construction phase (land occupation, materials use, energy for materials production and transport, etc.) as well as during operation for heating, lighting (represent by 33% of Spain energy consumption), water consumption, waste production, etc.[1,2].

The *Green Building* and *Sustainable Building* movements have arisen as response to the requirement for a construction sector more responsible with the environmental problems. This new design philosophy promotes the energy and natural resources consumption reduction, the use of renewable, the environmental impact mitigation, the waste production reduction and the improvement of citizen comfort and well-being. These aims can be achieved using sustainable measures and materials, innovative techniques for the building management, promoting the passive building design and water efficiency.

Also citizens, compromised with the environmental challenge, they demand more efficient urban environments capable to ensure well-being for the future. We have to point out that the definition of principles set to take into account the sustainable building approach is not an easy task. Generally, each designer employs several measures and solutions depending on the application context, according to client conditions and there know-how about the theme. It is more complex to define a measures' ensemble which sets the minimum standard in order to identify a construction work as *green building* or *sustainable building* [3].

The current regulation has developed a legal framework to promote building efficiency. In Spain, the Building Technical Code (CTE) has evolved towards the performance approach for design and set a minimum requirement about energy efficiency, indoor quality, acoustical insulation, comfort, etc. At international level, ISO and CEN have identified the sector need for a reference methodology of environmental assessment. International expert working groups has been lunched in order to found a general agreement for the assessment of several aspects involved in the building product.

The working group results have been collected in the following norms: EN 15643:2010 "Sustainability of construction works. Sustainability assessment of buildings." EN 15978:2011 "Sustainability of construction works — Assessment of environmental performance of buildings — Calculation method" and EN 15804 "Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products". These European Standards specify the calculation method, based on Life Cycle Assessment (LCA[1]) and other quantified environmental information, in order to assess the environmental performance of a building, and gives the means for the reporting and communication of the outcome of the assessment. The standard is available to new and existing buildings and refurbishment projects [4].

Objective

The need to promote buildings high quality and provide to the users clear information about the building performance, have been the driving force behind the development of various energetic-environmental assessment systems. Nowadays, these voluntary certifications are an additional element of quality more and more demanded for users. The number of certification systems has seen a staggering increase in the last thirty years, thanks to the effort of public and private organizations concerned on environmental challenge.

Among them, ECÓMETRO is a tool for the holistic evaluation based on several sustainable concepts applied to architecture. The tool, however ongoing developing, is result of open expert community contribution, which collaborates to achieve an agreement about criteria and method for the construction works assessment. According to the ongoing improvement, that is one of aim of the same community, the open debate for the comparison between the most

[1] Life Cicle Assessment: A systematic set of procedures for compiling and examining the inputs and outputs of materials and energy and the associated environmental impacts directly attributable to the functioning of a product or service system throughout its life cycle (ISO 14040.2 Draft: Life Cycle Assessment - Principles and Guidelines.).

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used assessment systems in Spain has been realized. The debate objective is to evaluate strengths and weaknesses of different tool in order to propose new solution for ECÓMETRO.

The open session has been organized with experts of the follows systems: LEED, Passivhaus, VERDE and ECÓMETRO. The results are shown in the comparison table that, beyond its application for ECÓMETRO development, can help to clarify differences and similitude between systems and it provides organized information for the designers which want to approach the building environmental assessment.

Environmental Assessment Systems for Buildings: LEED, Passivhaus, VERDE y ECÓMETRO.

Assessment systems for *Green Building* or *Sustainable Building* objective is establish a wide recognized standard, able to define an evaluation range, improving radically the relation between urbanized spaces and environment. This is possible by promoting comprehensive measures in building design, rewarding the effort to be more sustainable, improving the users and technicians knowledge about livability more responsible with the environment [4,5,6].

The first two questions we ask when we describe an assessment system are: *what measure it?* And *how measures it?* As shown in the comparison table, the systems use similar criteria/indicators, however the way to measure vary from system to system. The systems can be distinguished in two big groups according to evaluation method:

- **prescriptive** or **check-list systems**, composed by several measures or standard allocated with points or credits;
- And the **performance systems** where the assessment depends on the performance achieved for the building according to benchmarking.

The deeper observation of systems let to realize a major disaggregation of methodologies, identifying the phase in the Life Cycle, the score system (point or criteria weighting) and the result visualization. Also the certification process and the communication with the user it is very different (assessment review process, relevant entities, information transparence, etc.) The comparison results are presented in brief in the table below:

	Systems	**LEED**	**Passivhaus**	**VERDE**	**ECÓMETRO**
Methodology	Categories / Areas	1.Sustainable Site 2.Water Efficiency 3.Energy and Atmosphere 4.Materials and Resources 5.Indoor Environmental Quality	Energy Efficiency Thermal Comfort	A.Site Selection B.Energy and Atmosphere C.Natural Resources D.Indoor Environmental Quality E.Service Quality F.Socio-economic Impact	r. Relation with the surrounding m. Materials d. Design a. Water e. Energy
	Assess-ment	Point/check list. The allocation of points between credits is based on potential impact of each credit or design measures. The Prerequisite	Energy performance Assessment, verified with the Passive House Planning Package (PHPP). The building must meet following criteria:	Environmental and Socio-economic Impact Estimation, based on LCA methodology. The Impact Reduction calculation is obtained by compare the	Criteria and design strategies evaluation. The criteria's weight is allocated according community consensus.

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		set the minimum requirement to be eligible for certification.	Heating and cooling Energy Demand, Primary Energy Demand, Airtightness and Thermal Comfort.	building with base-line building. The assessment and final score is based on Impact Categories, according to UNE-EN 15978-2012	
	Performance/Prescriptive	Prescriptive: the point is obtained by achieving credit requirements.	Performance: -Energy Demand 15kWh, -Primary Energy Demand 120 kWh, -Airtightness 0,6 air change, -Comfort in summer and winter	Performance: achieve Impact Reduction from base-line building on 12 Impact Categories.	Performance, based on minimum requirement for each criteria.
	Phase in the Life Cycle	Design, Materials Production, Construction and Operation	Operation	Design, Materials Production, Construction, Operation, end of life and disposal.	Pre-design, Design, Materials Production, Construction, Operation, end of life and disposal.
	Result visualization	Final Score is a total point sum. The certification are awarded according to the following scale: Certified 40–49 points Silver 50–59 points Gold 60–79 points Platinum 80 points and above	The Certification document shows the final result of Energy Assessment.	The final result shows: the impact calculation, the impact reduction compared with base-line building, the final score is obtained by weighting impact categories according to 0-5 score. A graphic shows the impact reduction for each category.	The final result shows the score for each category that shape a graphic configuration in the pentagon result. 
	Flexibility/ Adaptability	The prescriptive systems allow some regional adaptation, but only for U.S. countries.	The PH defines design strategies for different climate zones.	The assessment is available to Spain conditions. The system can be adapted to other conditions through benchmarking modification.	The assessment is available to Spain conditions. The system can be developed and adapted to other conditions.
Certification	Certification Process	After the registration, the project design team should collect information and perform calculation to satisfy prerequisite and credit documentation. The evaluation has to be submitted to USGBC evaluation through LEED-Online systems. The registration and certification fees starting at 3950$.	The Passivhaus certification is available for building and construction products. Designers can realize the evaluation and send to Passivhaus Institute for the review. Certification cost vary case by case and the average budged is about 1400€.	To obtain VERDE Environmental Certificate the petitioner must include in his/her application an evaluation carried out by an Authorized Evaluator. Then GBCe carried out the Certificate revision in order to aware the VERDE certification. GBCe certifies buildings that are both in project phase or finished and in use. The certification fees starting at 1550€.	ECÓMETRO is open-source autoevaluation.
	Transparency	The assessment is based on TRACI environmental impacts categories, but the credit weighting is not explained.	The calculation system is based on energy performance simulation	The assessment methodology and weighting is explained. The users cannot modify the system.	The assessment methodology and weighting is explained and defined by community consensus. The users can modify the system.

Table 1. Comparison between environmental assessment tools.

The comparison shows that the categories/areas evaluated for the systems are very similar. The quite different between them are the assessment methodology employed: LEED is based

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on check list and prescriptive methodology where the certification is awarded achieving a minimum requirement. VERDE, Passivhaus and ECÓMETRO are performance systems that define the building evaluation allocated to criteria and benchmarking. Each system established own certification process, ECÓMETRO is the only one that is defined as autoevaluation and do not aware any certification [5,6,7,8].

Strengths and weaknesses of environmental assessment tools

The assessment systems analysis is focused on define strengths and better solution which can be used to propose a new assessment methodology for environmental tool for architecture products ECÓMETRO. For that, the expert community has shared the own experience in the tools use and finally has found a common agreement on better solutions for environmental assessment methodology.

The first question was choose between prescriptive or performance system. The community decided that performance systems are better for the follows reasons: at the first because is according to the philosophy of CTE and European directive about constructions works (2010/31/CE, UNE-EN 15643, UNE-EN 15978), at the second because the definition a performance leaves the architect perfectly free to propose different constructive solutions and introduce innovative technologies. The performance systems promote the on-going improvement in: technologies, designers' knowledge and assessment systems too.

Nevertheless, the performance systems entail more complex calculus, the criteria are difficult to accomplish and some times, are not easy to understand. For instance, VERDE is a complex tool, that need lots of exteriors calculus (energy, materials, water, ventilation, etc.) and the complete evaluation can be carried out only with the Final Project. To the contrary, the prescriptive method as LEED are easy to understand and can support the decision-making since the Preliminary Project phase as design guide for *Green Building*.

Then the second issue dealt for the expert community was *what measure* and *how measure it?* The community decides that the UNE-EN and LCA define a common conceptual framework and the assessment tools should to develop a methodology according to it. ECÓMETRO consider the LCA for construction materials (cradle-to-gate) while VERDE evaluate the sustainable impact of building along the Life Cycle (cradle-to-cradle). The VERDE methodology use the UNE-EN 15978 as reference to evaluate environmental as well as social and economic impact.

The last question discussed was the result and the visualization. For the expert community, the Passivhaus certification document is not communicative for non-expert users. LEED and VERDE use one final score as level of certification (certificate, silver, gold, and platinum for LEED and 0 to 5 for VERDE). On the one hand, the final score is an easy system to communicate to users and allows the comparison between different buildings. On the other, it do not shows the real quality of building, for instance a building could achieve very good performance in energy but negative evaluation in material selection: the one final score do not disclose to the users the building's strengths and weaknesses. ECÓMETRO focuses its efforts

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on define a clear, transparent and easy to understand visualization system. The pentagon represents the five evaluation areas and the graph shows the result achieved in each area.

Image 1. Visualization of final score achieved: ECÓMETRO, LEED, Passivhaus and VERDE. Source: ECÓMETRO, LEED Core Concept and Strategies online course

The Environmental Assessment diffusion has meant a general amelioration of buildings quality, giving a stronger impulsion to the *Green Building* market. Nevertheless, the existing systems show some weakness which limits the application of them. Especially the high cost of certification excludes a priori part of market, such as small buildings, self-built, low-cost housing and small suppliers. The certification process is also tedious and often lacks transparency, so the application is restricted to limited sector of professionals.

The successful keys for the wide application can be identified in the following points:
-Provide transparent, comprehensible and open-access evaluation tool.
-The system should be flexible to adaptation, for instance due to regional conditions, localization constraints, etc.
-Assessment methodology should be based on performance and ongoing updated, in order to integrate all innovation in calculus, technology and norms.
-Easy to use and friendly interface.

Proposal for future development of ECÓMETRO
In light of all comments and suggestions from experts, new solutions for ECÓMETRO development have been proposed and accepted from the user community. Currently, the ecometro alpha version is developing as an online tool, freely accessible on ECÓMETRO web page (http://ecometro.org/).

The ECÓMETRO methodology should be based on performance system and use the calculation approach according to UNE-EN 15978. The LCA is a referential framework and the final objective of environmental assessment is the building impact estimation. ECÓMETRO count with the LCA assessment tool and with generic construction products database linked with information about environmental impacts. The tool allows estimating the building environmental impact for construction materials production and transportation to site.

Regarding the impact categories, the assessment of social and economical issues is increasingly demanded for users, public partnership, stakeholders and social agents working in the real estate sector. In order to respond to this need, the next proposal for the ECÓMETRO methodology will introduce the socio-economical aspect in the environmental evaluation.

The evaluation methodology begins from the concept that each design strategy and architectural criteria produce environmental, social and economical impact. If we want to have a holistic view of building, the evaluation of three aspects should be carried out. For the impact evaluation, the technical group of ECÓMETRO is working in the impact list definition and weights allocation. The impacts list is being defined according to UNE-EN 15643-2-3-4 because ECÓMETRO is developing under the umbrella of European Directives framework. The work will be submitted to community for the discussion where, the same community, will approve, refuse, improve and/or modify the methodology proposed through open, horizontal and transparent process.

Also ECÓMETRO differ from the other tools because introduces the "mappa de aproximación", a tool for the first approach to building design. The tool asks to the designer to answer several questions about the building location context, such as: density development, climate conditions, site contamination, etc. The tool seeks to raise awareness of the site condition in order to define design constraints at an early stage of project process. ECÓMETRO is not only an assessment tool, but strive for be a new approach to building design for both: new construction and building/urban renovation.

The tool is an open source platform where input from other tools and systems can be inserted and evaluated. For instance the technical team is working on the construction materials impact estimation calculated using the project metric estimation files. The next step will be introduced a GIS[2] system to georeference the several site information in the same map. Other information as resources localization could be an effective support to find regional materials. The open source system will ensure sharing information thank to collaborative approach: each autoevaluation needs to insert some input information in the system which the other users can visualize. Also the same community will review, validate or correct the information introduced (quasi) real time.

ECÓMETRO is a new tool that brings together the more innovative concepts about green building: a. an extensive criteria evaluation, b. environmental, economical and social impact

[2] GIS: Geographic Information System is a computer system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data. (ESRI. Retrieved 9 June 2011)

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assessment, c. open source platform able to receive inputs from other systems as BIM[3] and GIS software, d. collaborative approach supported by web community. ECÓMETRO aims to be an answer for the society request for a system able to provide a holistic view of architectural products and guide the designers toward a new project approach.

Bibliography

[1] de Diego, Margarita de Luxán García. Arquitectura Integrada En El Medio Ambiente. *Cuadernos De Investigación Urbanística*, 2011, no. 41.
[2] E2B Association. *Home page*. 24-04-2014. http://www.e2b-ei.eu/default.php. Accessed: 26-05-2014.
[3] MELIS, Paolo. *La Valutazione Della Qualità Globale Degli Edifici Residenziali Nella Programmazione Degli Interventi Di Riqualificazione Alla Scala Del Patrimonio Edilizio*. Universita'degli Studi di Cagliari, 2011.
[4] CEN/TC 350. *AFNOR Normalisation*. 2012. http://portailgroupe.afnor.fr/public_espacenormalisation/CENTC350/index.html. Accessed: 26-05-2014.
[5] WordPress. Clasificaxiones. 26 marzo 2007, 2007Available from:<http://habitaxion.wordpress.com/category/agua/>. Accessed: 26-05-2014.
[6] SB Method and SBTool. iiSBE-International Initiative for a Sustainable Built Environment. 2009. http://www.iisbe.org/sbmethod. Accessed: 26-05-2014.
[7] AA.VV. *LEED Reference Guide for Green Building Design and Construction*. U.S. Green Building Council. 2009. Washington, DC
[8] Plataforma de Edificación Española. *El Estandard. Certificación*. http://www.plataforma-pep.org/presentacion. Accessed: 26-05-2014.
[9] ecómetro associación. *Blog*. 2014. http://blog.ecometro.org/. Accessed: 26-05-2014.

[3] BIM: Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition. (National BIM Standard – United States. National Building Information Model Standard Project Committee, http://www.nationalbimstandard.org/faq.php#faq1. accessed: 20 November 2013)

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Social performance criteria for buildings according to the CEN TC 350: Case study of the assessment of the VELUX Sunlight-House, Austria

Speakers:

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Abstract: *Recently the new standard EN 16309 has been approved with the methodologies for the social performance assessment of buildings. The social dimension according to this standard contains six main categories: accessibility, adaptability, health & comfort, impacts on neighbourhood, maintenance and safety & security. 22 aspects determine the social performance of the building's use stage within these categories.*

In this paper we present the first case study on a building that has been assessed according to the EN 16309. The building in the case study is the VELUX model-home in Austria, named the "Sunlight-house". The building is optimized for high indoor quality and for zero CO2-emissions during operation. A young family was living in the sunlight-house for one year.

In our analysis we discuss assessment rules defined in the standard EN 16309, and we compare the assessment results with two other assessment systems and take a critical look on the EN16309 methodology.

Keywords: Social performance assessment, building sustainability assessment, CEN TC 350, EN 16309, Sunlight-House

Introduction

While the environmental performance of buildings is a well-studied field of expertise social impacts and aspects are not so prominent in assessment systems. Several social aspects are covered in existing assessment schemes which have been developed in the past. To mention the most known: BREEAM (developed by BRE, UK), LEED (by US-GBC, US) and DGNB (Deutsches Gütesiegel für Nachhaltiges Bauen, DGNB, Germany). These building rating schemes contain a variety of social aspects although in a rather unsystematic manner.

This has been described by Tritthart and Rohracher [1]. They proposed a systematisation according to the 'system-level' of its impact, i.e. from social aspects of building use to social impacts of the building on its neighbourhood / local environment and the broader impacts of the building on society at large (e.g. cultural heritage).

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Within the CEN Technical Committee 350 ("Sustainability of construction works") the social part has been always an integrated aspect of the sustainability assessment. Recently the new standard EN 16309, dealing with the methods for social performance assessment of buildings, was issued. EN16309 provides a structured quantification of social performance of buildings but does not provide a rating scheme for the quantified results. This standard contains six main categories of social issues: accessibility, adaptability, health & comfort, impacts on neighbourhood, maintenance and safety & security. Within these categories 22 aspects determine the social performance of the building's use stage. During the development of the standard more aspect categories of social performance were considered, but deemed not to be ready for standardisation, e.g cultural heritage. It was also decided that the standard had to be limited to the narrow focus of the impact that the building has on its user and inhabitants [2].

In this paper we present the first case study building that has been analysed according to the EN 16309. The case study building is the VELUX model home in Austria, named the "Sunlight-House". The building is optimized for high indoor quality and for zero CO_2-emissions during operation. The building is a single family home near Vienna. A family (four persons) lived in the house for one year.

The house has been monitored thoroughly and the measurements have been used for the assessment of the building according to (1) the Active house specification and (2) the Austrian TQB system. The measurements were carried out for 1 year and were accompanied by a qualitative survey on the living-satisfaction and experiences of use by the building users.

We present some indicators of the EN 16309 and their evaluation and documentation in depth. We show the results and compare them to results of the above mentioned two assessment systems.

Social performance assessment according to the EN 16309-standard

After identifying the Goal of the assessment and the intended use of the object of assessment, i.e. the building - the object of assessment - is further specified by describing the functional equivalent, the reference study period, scenarios and the system boundaries.

The functional equivalent comprises all information from the building that is relevant to derive the functional unit for the building itself, for all building elements, components and materials. The system boundaries of the object of assessment are the building, its foundations and external works within the area of the building's site (curtilage) and temporary works associated with the building's construction or refurbishment.

Assessments are to be established on the basis of scenarios that represent the time-related information of building life cycle stages. The scenarios shall be realistic and representative and in accordance with the technical and functional requirements. Technical aspects such as operating time, operating frequency, maintainability, frequency of maintenance, replacement aspects, lifetime, etc., shall be taken into account in the scenarios for the social performance assessment, Scenarios will be a key-information in the social part to check the relevance of

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indicators and allows to assess how activities, circumstances and conditions impact the user in using the building [2].

The standard EN16309 intends to first determine whether any of the indicators are the subject of national, regional, or local regulation/legislation or a client´s requirement. If any of these stipulates performance, it shall be stated to which degree the building improves upon the requirement.

Description of the Sunlight-House in terms of the CEN TC 350-standard

The VELUX-Sunlight-House has been registered as an outstanding sustainable building; detailed measurements of the indoor conditions, the daylighting and the energy consumption were performed by Danube-University Krems (Austria) [5] and VELUX itself. The Danube-University Krems and Velux measurements have been used as an input for the assessment of the building.

The functional equivalent of the Sunlight-House is set up as a single family house for 2 adults and 2 children in Preßbaum, a village in Lower Austria, which is located in the outskirts of Vienna. The client (VELUX Austria) issued an architectural competition for the design. The tender document ("Auslobungunterlagen geladener Realisierungswettbewerb VELUX Demohaus") was taken as the client's brief for the EN 16309 assessment.

The client`s intention was to prove that an ambitious energy performance (zero energy building) could be realized without meeting all the prescriptive demands of the Passive House standard. Daylighting should be abundant, without leading to overheating in summer. It should be demonstrated that with the VELUX systems and products applied in a good design (roof windows, solar collectors and PV, WindowMaster control system for natural ventilation and sun shading) a high comfort level and the EU's zero energy performance for a building can be realised. The location (a building plot) was already acquired by the client. After 1 year of monitoring during which the house was inhabited by a family the property was sold.

The chosen building design has two floors and a basement, a courtyard (atrium) and a big roof area to the south that includes the solar systems and introduces day light to the living room by means of roof windows (see fig. 1).

The legal requirements consisted of mainly three construction related laws that are in force concerning the construction in the region. The scenarios are proposed on the basis of the requirements of the client. As demanded by EN 16309 they are given for all information modules. The scenario for normal use (information module B1) is:

(1) The house is inhabited by a family with two younger kids,
(2) the house is inhabited by a family with two teenage kids and
(3) visitors which are elderly or with a handicap are expected.

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Aspects and criteria evaluation for the Sunlight-House

The assessment methodology in EN 16309 demands to track the relevant aspects for the building`s use. The first decision for the assessor to make on each indicator is on the relevancy of each (sub-)aspect. For this the functional equivalent of the building has to be consulted, as well as the client`s brief and legal requirements: What is the building constructed for, What are its functional and technical requirements?

In the following some important aspects are presented in order to illustrate the process, the results of the assessment and the documentation. The results are part of a tabeled structure that is suggested as an adequate presentation that contains all information on the assessment process in a structured way (Annex A of EN 16309). Then the project paper continues with a comparison of the EN16309-assessment with the Active House- and TQB-Assessments.

Table 1 demonstrates the concept of the EN16309-performance assessment and contains also one indicator of the aspect "accessibility" and one of the aspect "thermal comfort" as an example:

Indicators for the aspect related to social performance	Is the aspect relevant for the design of the object of assessment ? Or is the indicator not assessed (INA)?	Is there a national-regional or European requirement applicable? (yes/no) If yes - give Reference to the relevant regulation)	Specify the minimum requirement according to the prevailing regulation or if not regulated give details of any requirements made in the clients brief (If none state "none")	Have measures been taken for exceeding the requirements given in the left colum? (yes/no)	Give value for indicator or briefly specify measures taken to achieve the stated performance ?	Give Reference to relevant documenta-tion
Accessibility – approach to the building: "The number and distance of dedicated drop-off and pick up points from the entrance"	YES	No	None	YES	< 5 m	See drawings "EINREICH-PLAN"
Health and comfort – Thermal character-ristics: "Operative temperature"	YES	No	None	YES	Measures: passive solar gains, night ventilation	See report DUK (fig. 2)

Table 1: Concept of the social performance assessment (EN 16309)

Accessibility evaluation

Accessibility means the characteristic of the building that it may be entered (and left) by all people – also those with special problems and needs. No performance-oriented indicator for the accessibility of a building has been developed by now. Instead accessibility is usually

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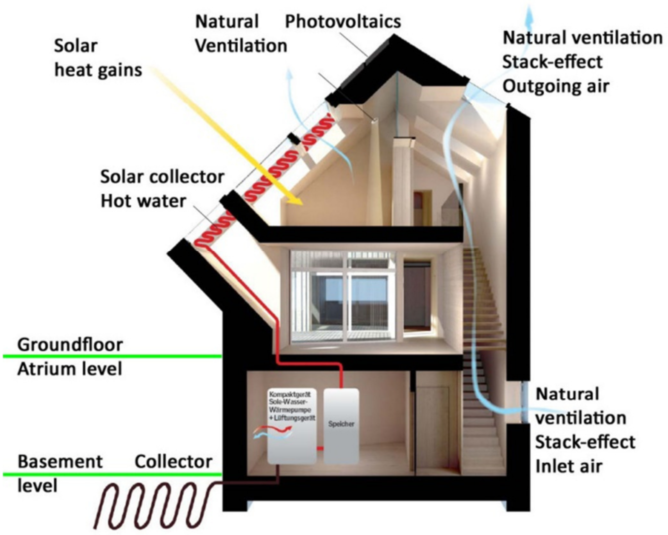
described by design guidelines and recommendations, like the minimum width of corridors and maximum slope of a ramp that can be passed by wheelchaired people, Similar design solutions have been developed in most European countries. They are often implemented in national design standards or prescribed as minimum requirements in rules, regulations or codes of practice.

In the EN 16309 three aspects are evaluated: the approach to the building (this is the situation outside of the building), the entrance to and the movement inside the building, the access to building services. Whether all facets or indicators of these aspects are relevant to be assessed for this building depends crucially on the scenario that is chosen: What will be the uses the building is designed for? For the Sunlight-House the scenario was explicated in the chapter "Description of the Sunlight-House in terms of the CEN TC 350-standard".

Since the building is designed for a family with no wheel-chaired persons, the design solution stresses the entrance which is barrier-free (for parents with pram or with heavy shopping-bags). But there is a staircase to the upper floor and to the basement (see fig. 1). Children have to be kept from falling down by additional equipment (left up to the parents). Visitors and guests find a bathroom and a toilet on all floors. Furthermore the building allows for an adaptation to result in a completely barrier-free home. An according design-scheme has been drawn and provided to the client by the architect.

The assessment of the indicators needs as an input the drawings for building permission ("Einreichplan"), special drawings (for barrierfree adaptation) and specifications of sanitary equipment.



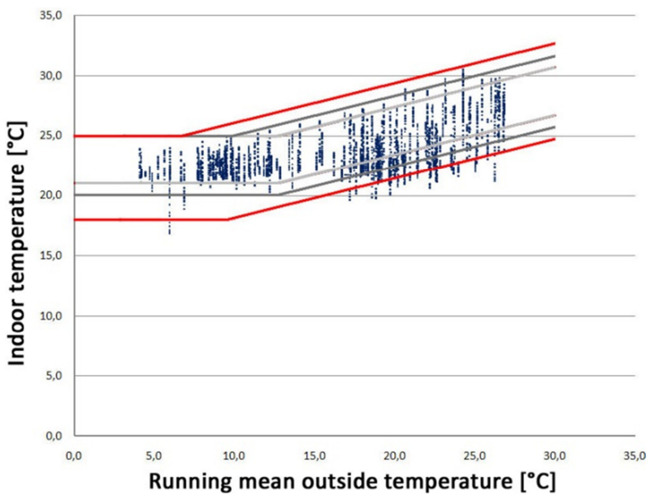


Figure 1 (left): Sectional view of VELUX Sunlight-House, energy systems and components [5]
Figure 2 (right): Comfort evaluation (measuring data for operation temperature) according to EN 15251 [5]

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Thermal comfort evaluation

Thermal comfort is probably the most prominent aspect of indoor comfort. Thermal comfort is described as 'that condition of mind which expresses satisfaction with the thermal environment' [6]. The adaptive modell [7] accounts for the observation that people adapt themselves to their thermal environment by various actions (clothing, posture, activity, opening windows, adjusting blinds, adjusting heating or cooling). This modell is used in the comfort classification of EN 15251.

The operative temperature has been measured in all rooms of the Sunlight-House. The Data are printed as a function of the running mean outdoor temperature (see fig.2), which has been found to be the best predictor variable [8].

The scenario will gain importance as soon as the results of the assessment are rated, because the classification of EN 15251 involves different building uses and levels of expectations concerning fluctuations of the temperature.

Comparison of EN 16309 and other assessment systems

The main categories of the "Active House Specification" are shown in Fig.3. The system covers indoor environment, resources (energy and water) and environmental loads caused by building materials, but it is clearly focussed on indoor environment prescribing several elaborated indicators and drawing on the classification in EN 15251. Some related issues like acoustics or emissions to the indoor air that are affecting health, are not dealt with. On the other hand the "Active house Specification" comprises also control- and use-related issues.

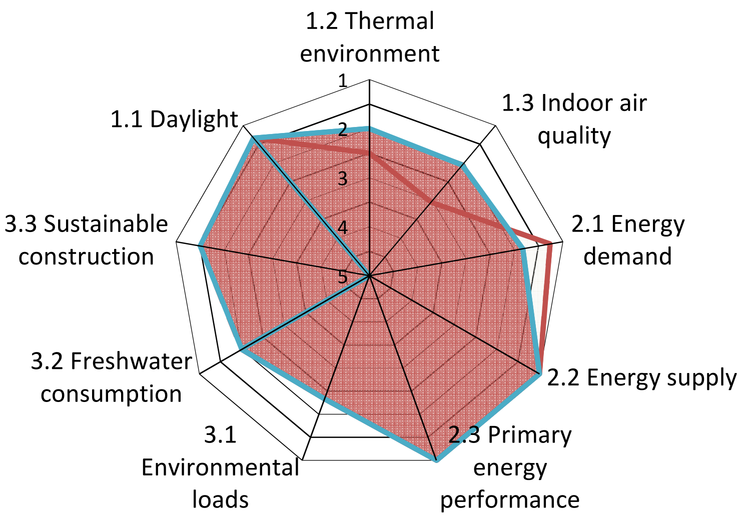

Figure 3 (left): Results of the evaluation with "Active House Specification" [5]
Figure 4 (right): Results of the evaluation with "TQB" (IBO, 2013)

Four indicators on three (of the 22) aspects of EN 16309 are in full conformity. So these results can be directly used for the EN 16309-assessment. E.g. the operative temperature that is the most important indicator for the thermal comfort condition has been evaluated for the Sunlight-House and is shown in fig. 2.

The Austrian “TQB – Total quality building” assessment system thrives to promote a comprehensive sustainability assessment. It was developed from the Green Building Challenge framework in 2001 and constantly adapted [9]. The five categories of the TQB-system are: location and amenities, economical and technical quality, energy and water, health and comfort, resource efficiency. In the TBQ system in each category a maximum of 200 points can be earned, giving a “top-rating” of 1000 points. The VELUX Sunlight-House reached 931 points in the TBQ rating.

The TQB-system has several aspects and indicators in common with the EN 16309. These aspects all originate from the categories: accessibility, adaptability, health and comfort, safety and security. 13 aspects out of the 22 EN16309-aspects are also addressed in TQB. Usually TQB requires only one or two indicators per aspect, whereas EN 16309 has always several indicators per aspect which however might not require extensive measurement series like e.g. in fig.2, but can be a simple question, to be answered with “yes” or “no”. So the TQB-assessment cannot directly be transferred into EN 16309-assessment.

Conclusions

This paper shows that the new standard EN 16309 is ready to be used for the social performance assessment of buildings. Its range of aspects is also found in other existing building assessment systems. But even comprehensive systems do not ask for as many indicators for each aspect. This may be due to the fact that the EN 16309 is generally applicable for all building types and uses. EN 16309 could serve as a basis for national assessment systems that further specify which indicators have to be assessed and which benchmarks are available. Depending on the building type and on the building use the client and/or the assessor decide which social indicator is relevant.

Thermal comfort and health are quite well represented in all assessment systems. Also accessibility and fire safety requirements are traditional issues of assessment systems. These functional and technical related performance indicators are evaluated using checklist items. Benchmarks for these aspects provide the applicable national or international requirements. A performance of the building above this minimum requirement is deemed as a superior social performance that is highlighted by the assessment.

References

[1] Tritthart, W.; Rohracher, H. (2011). The social sustainability of construction works – Challenges and pitfalls for integrating social dimensions into the sustainability assessment of buildings. Proceedings of the World sustainable buildings conference 2011, 18 – 21 October 2011, Helsinki.

[2] Hamans C.; Tritthart W. (2013): Social performance assessment of buildings according to the European standard prEN 16309. In: FULL Papers of the International conference on Sustainable Buildings – Construction Products & Technologies, ISBN (E-Book): 978-3-85125-301-6, http://dx.medra.org/10.3217/978-3-85125-301-6. Verlag der Technischen Universität Graz. 629 - 640
[3] EN 15643-3:2012. Sustainability of construction works. Assessment of buildings. Framework for the assessment of social performance
[4] EN 16309:2014 Sustainability of construction works - Assessment of social performance of buildings - Calculation methodology
[5] Danube-University Krems (2013). Yearly report VELUX model home Austria Sunlight-House. Unpublished report, date: 2013-07-17, Danube-University Krems, Departement for Building and Environment.
[6] Fanger P.O. (1970). Thermal comfort. Copenhagen. Danish Technical Press.
[7] Nicol, J.F.; Humphreys M.A. (1973). Thermal comfort as part of a self-regulating system Building Res. Pract. 6(3).
[8] Humphreys, M.A.; Rijal, H.B.; Nicol, J.F. (2013). Updating the adaptive relation between climate and comfort indoors; new insights and an extended database. Building and Environment 63, 40-55.
[9] Geissler, S.; Bruck, M. (2001). ECO-Building-Optimierung von Gebäuden durch Total Quality Assessment (TQ-Bewertung). Berichte aus Energie- und Umweltforschung 29/2001, Wien.

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DGNB Certification System

Author: *Michael Dax, German Sustainable Building Council (DGNB)*

Abstract: *The DGNB System is a transparent and user-friendly tool for the planning, assessment, and certification of sustainable buildings and urban districts. It offers a comprehensive quality concept and is based on a holistic view of our built environment. It considers a building's entire life-cycle and makes a balanced evaluation of six different areas: environmental, economic, socio-cultural and functional aspects, technology, processes, and the building site.*

The DGNB System defines clear sustainability targets that can already be used in the planning phase to optimize the respective design. It is based on a strong community of players from all sectors of the construction and real estate industry as well as from academia. Interdisciplinary committees and a neutral review process ensure high quality as well as a comprehensive expertise.

The DGNB System is based on European laws, standards, and technical guidelines. Thus it is perfectly suited for a direct use in many countries.

Sociocultural and functional aspects / existing building stock / sustainable urban districts / industrial buildings

Section A – Sustainability Indicators, A2 + A3 – Buildings and neighbourhoods

1. General Introduction

The DGNB certification system is a rating tool for the built environment developed by the German Sustainable Building Council (equally called DGNB). Its objective is to assist in the design, realization and management of sustainable buildings. The system not only gives a comprehensive description of sustainability in the built environment, but also makes it possible to objectively assess a buildings (or urban district's) overall performance. The DGNB System can be applied to new and existing buildings as well as to urban districts. The DGNB System offers a comprehensive definition of sustainability in the building sector that can help to make a real step ahead towards a better built environment benefiting all of us - today, tomorrow, and beyond.

2. The German Sustainable Building Council

The German Sustainable Building Council (DGNB) was founded in Stuttgart, Germany, in June 2007. Currently its membership amounts to more than 1,150 organizations and institutions, representing all areas of the building and real estate sectors. DGNB is a non-

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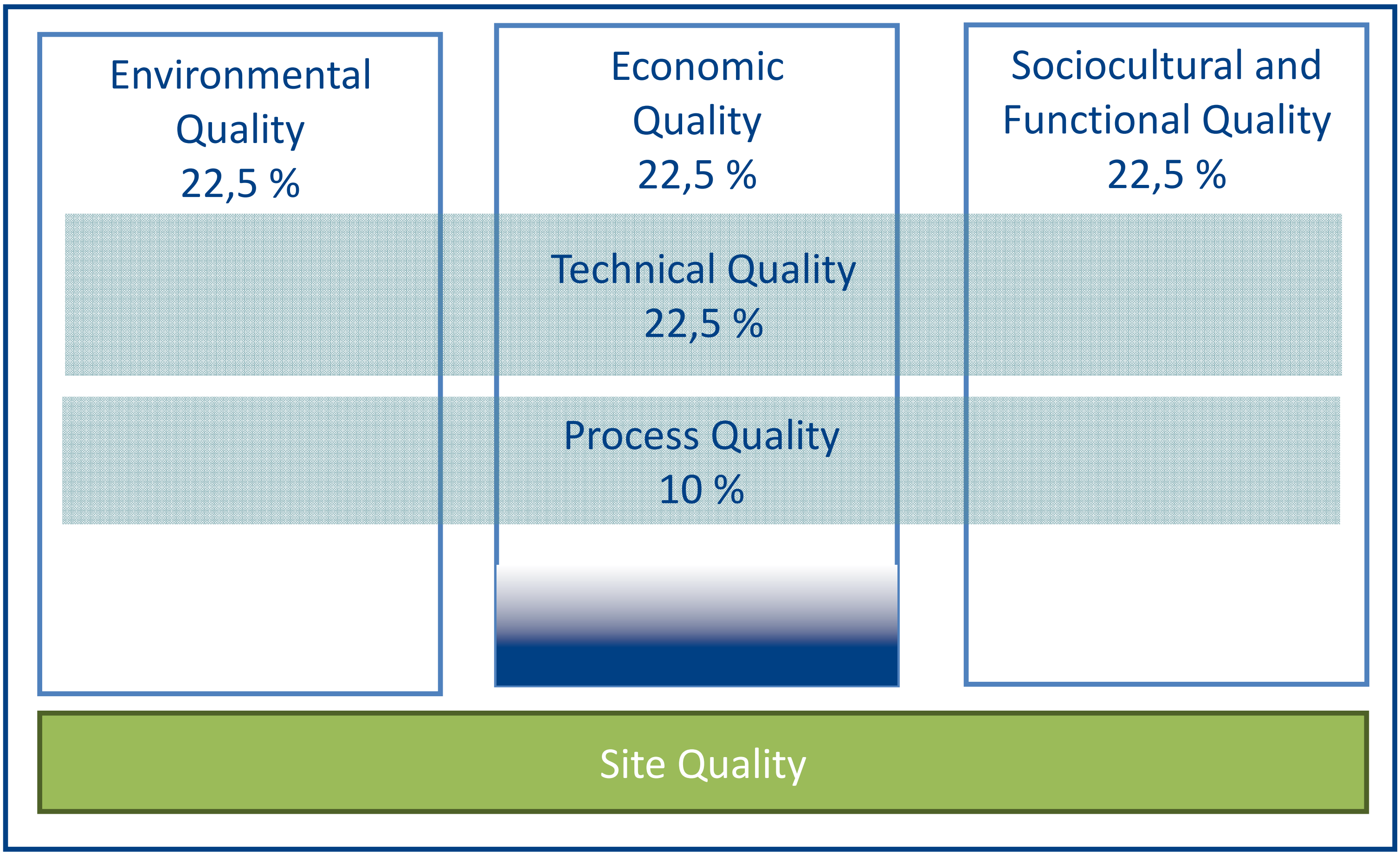
profit and non-governmental association. The German Sustainable Building Council is the owner and developer of the DGNB Certification System.

3. The DGNB System - Basic Structure

The DGNB System considers six areas of evaluation as follows:

- Environmental Quality
- Economic Quality
- Socio-Cultural and Functional Quality
- Technical Quality
- Process Quality
- Site Quality



In the overall evaluation these six areas are weighted according to a specific pre-defined importance. Economic quality, environmental quality, socio-cultural and functional quality as well as technical quality each make up 22.5 per cent of a building's total performance index, with process quality contributing 10 per cent. In the case of buildings, the quality of the location is not included in the total performance index but is evaluated separately; in the case of urban districts, the site quality is an integral part of the total performance index.

Each of the six evaluation areas is divided into several criteria, such as energy demand, acoustic quality, or space demand. For each criterion, measurable target values are defined and measurement methods and documentation required for verification are clearly outlined. A maximum of ten points is given for each criterion. Depending on the usage profile, each criterion also has a specific weighting factor. This weighting factor reflects a criterion's societal and political relevance. A building's energy demand, for example, is thus deemed more important than acoustic comfort. Depending on the extent the requirements were fulfilled, the certificate is awarded in bronze, silver, or gold.

4. The DGNB System - The Rating Process

Clear targets have been defined for each criterion of the DGNB Certification System. Auditors award a score of up to ten points based on the degree to which a criterion has been fulfilled. All criteria in an evaluation section are then condensed into a partial score. The scores for economic, environmental, socio-cultural and functional, and technical quality each account for 22.5 percent of the overall evaluation of a building or urban district, whilst process quality accounts for 10 percent. Site quality is considered separately in the case of buildings, but is included in the criteria for urban districts.

If the total score is at least 50 percent, for instance, the building (or urban district) will receive a bronze DGNB Certificate. If the total score is at least 65 percent, a silver certificate is granted. To qualify for a gold certificate, a project requires a total score of at least 80 percent. The DGNB aims to promote a uniform quality standard for buildings. Therefore the total score alone is not sufficient for a certificate. In addition, the performance in each of the evaluation section must reach a specific minimum level in order for a certificate to be issued. For instance, gold requires a score of at least 65 percent in all evaluation areas. Similarly, silver requires a score of at least 50 percent in all evaluation areas, while bronze requires a minimum of 35 percent.

5. The DGNB System - Available Schemes and Schemes under Development

The following schemes are currently available with the DGNB System:

New construction
. Office and Administrative Buildings
. Retail Buildings
. Residential Buildings

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. Hotels
. Educational Buildings
. Industrial Buildings
. Hospitals
. Laboratory buildings
. Mixed use
. Urban districts
. Industrial districts

Existing
. Office and Administrative Buildings
. Retail Buildings
. Residential Buildings
. Industrial Buildings

The following schemes are currently under development:
. Assembly buildings
. Stadiums and sport facilities
. Fit out

6. The DGNB System - International Use and Adaptation

The DGNB System was developed in order to provide a certification system based on international codes and standards making it easy to use in various countries while at the same time provide the high quality and transparency based on the DGNB philosophy. The system, available entirely in English, bases each of its criteria on corresponding European Standards.

The DGNB System is the first, and to date the only system worldwide in which the procedure for adaptation to different countries is an integral part of the system itself. This adaptation takes into account different climatic zones, associated cost-benchmarks, and a specific database for life-cycle assessment, within which the datasets for all European countries are made available.

The DGNB has the goal of optimally adapting its certification system to requirements in other countries with the help of close partner-ships with local non-profit and non-governmental organizations. An important objective of DGNB is to ensure the high quality of these adaptations. An international board of representatives of the DGNB and its partner organizations ensures the high quality standard worldwide. The Austrian Green Building Council ÖGNI was the first to adapt the system. Bulgaria, Denmark, and Switzerland have also founded their organizations and adapted the system to their specific needs. Other countries such as China, Brazil and Thailand are currently following suit.

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7. The DGNB System - What Is Specific About It?

a) With a unified basis the evaluation of the building is possible in every stage of the building life-cycle with the same comprehensive quality approach

b) Embedded LCA (Life-Cycle Assessment): Systematic analysis of the environmental impact of products during their entire life-cycle. Harmonized by international standards (ISO 14040 / 14044)

c) Emphasis on LCC (Life-Cycle Costing): Total cost throughout the entire life-cycle incl. selected construction, operation and maintenance costs directly attributable to owing or using the asset

d) Focus on performance and targets: Assessment of the building as whole, not individual measures

e) Dynamic System: Adaptable to other technical, societal, cultural and climatic conditions

f) Future-Oriented: Based on international standards and guidelines (e.g. CEN/TC 350 etc.)

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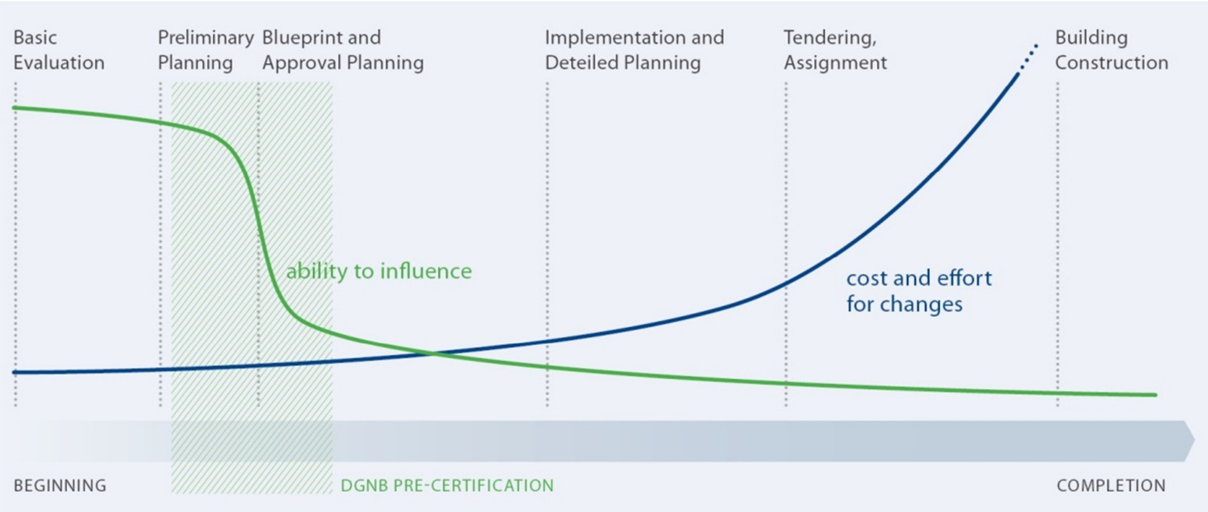
g) Pre-certification with DGNB criteria as a guiding instrument in the planning phase defines specific performance objectives and promotes an integrated planning process



8. DGNB Academy

The DGNB Academy comprises three sections. For a broad professional public, it provides general knowledge about topics relevant to sustainable construction. This provides you with the DGNB Registered Professional (RP) qualification. If you view the DGNB Certification System as a career opportunity, you can acquire the requisite knowledge to use the DGNB System nationally and internationally by gaining the DGNB Consultant and DGNB Auditor qualifications. Finally, we share our comprehensive know-how on specialist topics of sustainable construction by offering seminar program and in-house training formats tailored specifically to meet the requirements of our member companies.

9. DGNB Navigator

You need the right products in order to plan and build sustainable buildings. The DGNB Navigator provides the relevant information in a simple and easy to use format. The online platform provides well-informed answers to your questions about products and other important factors in sustainability. Auditors and planners can find exactly the product data they need to make the right decision for their project. Manufacturers can find out which data is required in which format for working with the DGNB System. The DGNB Navigator thereby provides an important interface between all the important stakeholders. An intelligent search function allows you to capture key facts about products' technical properties and their environmental, economic and health-related aspects.

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10. Certified Projects

To date, some 530 buildings have been awarded DGNB Certificates or Pre-certificates in Germany and abroad, with an estimated 400 projects currently registered for certification.

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Session 16:

How can traditional architecture contribute to sustainability? (I)

Chairperson:

Solé, Josep

European Sustainability and Technical Manager at URSA Insulation. Barcelona, Spain

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Assessment of Existing and Historical Buildings in Terms of Sustainability – Case Studies in the Czech Conditions

Speakers:
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[2] CTU In Prague, Faculty Of Civil Engineering, Prague, Czech Republic

Abstract: *If cultural-historical value is recognized in a building then the Czech multicriterion assessment methodology for buildings reSBToolCZ involves it into the assessment following the so called improvement potential principle. The cultural-historical value is not mathematically measured rather than used as a limitation for refurbishment.*

Resulting assessment provides us an answer to a question if it is better to use the old building and refurbish it or if it is better to demolish it and build a new one with much better sustainability profile.

This paper presents several case studies of assessment of building refurbishments which were used for setup of reSBToolCZ. These studies were made on various residential buildings with different age, size and historical significance. The results showed that majority of existing buildings can be improved to a level in which their environmental performance is very good and comparable to a new environmentally optimized building.

Keywords: building refurbishment, historical buildings, multicriterion assessment of buildings, sustainable buildings, cultural-historical value

1 Introduction

SBToolCZ as the Czech national scheme for complex multicriterion assessment has been started in 2010. The number of assessed and certified buildings is still rising. Till May 2014 the number has exceeded over 20 issued certificates. This scheme has been developed and used for new residential buildings. At the same time the development of the methodology reSBToolCZ for existing residential buildings and their renovations was started.

The main aspect that, in contrast to new buildings, affects renovations of existing buildings is their cultural-historical value. It has a fundamental influence on potential renovations and also on the scale of improvements of the overall building profile. It is obvious that it is necessary to approach differently to a building with cultural-historical value and a building with minor cultural-historical significance.

With this in mind, the basic principles of the methodology were developed and tested.

The major differences between new and existing buildings occur in their environmental performance which is connected to the first group of Environmental criteria in the reSBToolCZ (Table 1).

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Group	Weight [%]
Environmental criteria	50
Social criteria	35
Economics and management	15
Locality	0
Total	**100**

Table 1. Groups of criteria in SBToolCZ/reSBToolCZ and their weights.

Therefore, this paper focuses on environmental criteria of existing buildings which were examined on particular case studies. These case studies were carried out in order to answer the questions if the existing buildings are worth renovating and what is their actual environmental performance in current state.

1.1 ReSBToolCZ – basic principles

The methodology reSBToolCZ is based on these principles:

a) Mutual comparability between assessments of existing and new residential buildings:
   - same weights of groups of criteria;
   - same social and economic qualities within the groups of criteria.

b) Cultural-historical value and heritage legacy should be taken into account in the assessment of existing buildings because it is an inseparable part of their quality.

c) The assessment should provide a complex answer to the question if it is better to refurbish an existing building or build a new one with better performance in SBToolCZ criteria.

These principles are based on two premises. First one says that living in buildings and level of comfort that people require in them is the same whether the building is new or not. The second one is that if society wants to reach sustainability in all senses of its meaning, then the assessment has to take into account cultural-historical value.

Then the decision making process whether the building has or does not have a cultural-historical value becomes a part of the assessment. The criteria are modified according to this decision. Criteria that are influenced by the cultural-historical significance are those connected to the envelope and look of the building (Table 2.).

Criteria		Influenced
E.01	Primary energy consumption	YES
E.02	Global warming potential	YES
E.03	Acidification potential	YES
E.04	Eutrophication potential	YES
E.05	Ozone depletion potential	YES
E.06	Photochemical ozone creation potential	YES

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E.07	Renewable energy production	NO
E.08	Use of building materials during construction	NO
E.09	Use of certified building products	NO
E.10	Potable water consumption	NO
E.11	Outcome of rainwater	NO
E.12	Land use*	-
E.13	Use of greenery on building site and constructions	YES
E.14	Ecological value of site	NO

**Not applicable for existing buildings. Weights are redistributed among other criteria.*

Table 2. Environmental criteria influenced by the cultural-historical significance of the building.

1.2 Improvement potential

The criteria where it is necessary to take into account cultural-historical value are modified. This relative modification of benchmarks is called the improvement potential. This represents the scale of possible improvement which is limited by the cultural-historical value (Figure 1).

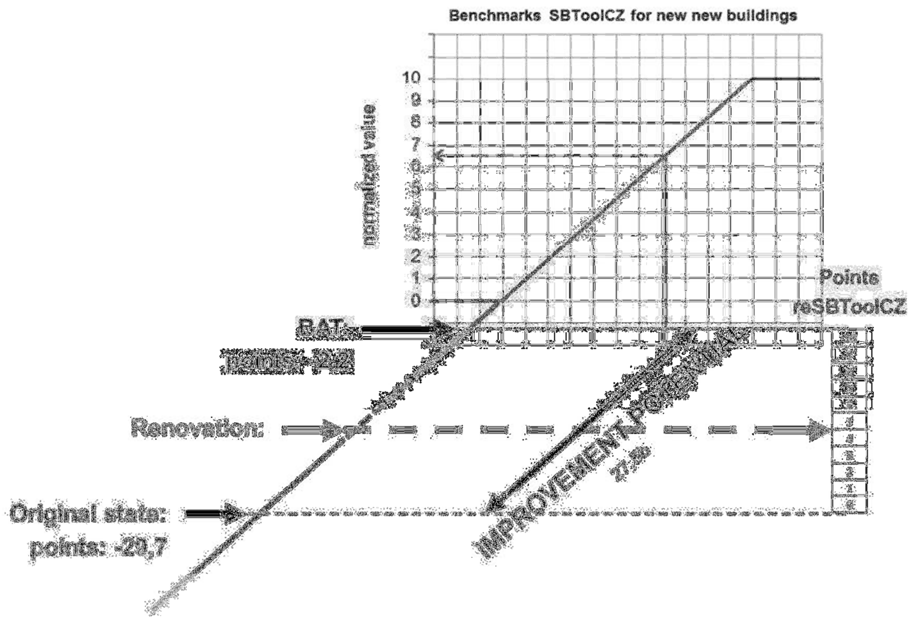

Figure 1 Example of benchmark setup by the improvement potential.

Benchmark settings are relative which means that they are always set up ad hoc building from to building according to the evaluation of original state and definition of the best available technique (BAT) solution for the building. Then the proposed solution lies in the interval between the original state and the BAT <original state; BAT>. The difference between these two points is called the improvement potential (Figure 1).

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1.3 Embodied indicators

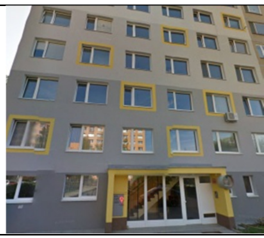
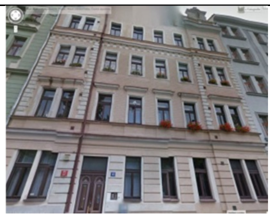
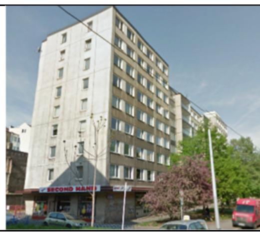
In those criteria where embodied indicators are measured (from E.01 to E.06) the assessment takes into account only materials that are being added to the existing construction during renovation process.

This principle is based on an assumption that the environmental load is not rising because of the building constructions that are already implemented in the building. Eventually, this approach has several consequences or effects:

- In comparison to the assessment of new buildings the existing ones are advantageous in the sense of embodied indicators.
- Encouragement of renovation of existing buildings rather than building new ones.

1.4 Case studies

Testing assessment of the reSBToolCZ approach in environmental criteria improvement potential was carried out on 11 existing buildings. These buildings are all residential with different level of cultural-historical significance.

Praha, Branická 1242/32	Praha, Ječná 29*	Praha, K lukám 646	Moravské Budějovice, Chelčického ul.
			
Praha, Na Zatlance 8*	Praha, Nad královskou oborou 171*	Praha, Nuselská 29	Praha, Pod Sídlištěm 195
			
Praha, Rubešova 1/41*	Praha, Ruská 66/745*	Praha, Trojanova 337/9*	
			

**Buildings with cultural-historical value*

Table 3 Case studies buildings

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2 Methods

The assessment procedure of an existing building and its renovation has several steps (Figure 2). These steps have to be followed. In case of culturally significant building the criteria that are influenced by it (Table 2) have to be adjusted with the improvement potential setup (Figure 1).

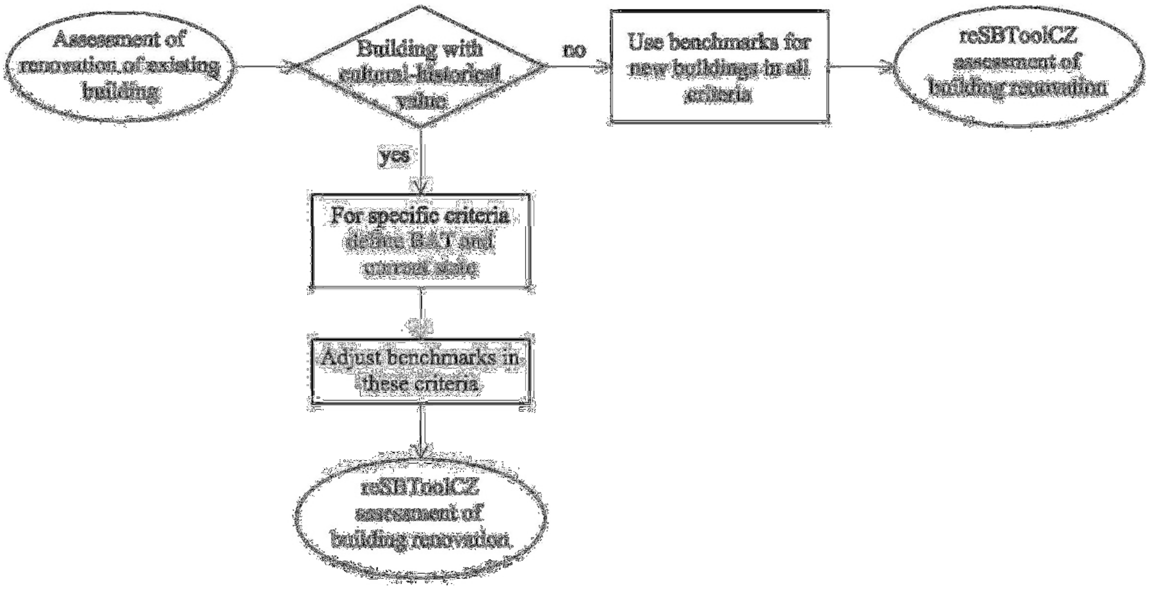
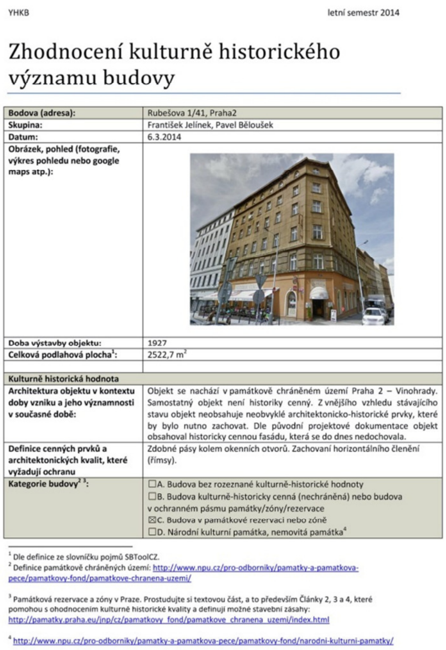


Figure 2 Assessment of existing building procedure..

2.1 Assessment of cultural historical value



YHKB letní semestr 2014

Zhodnocení kulturně historického významu budovy

Bodova (adresa):	Rubešova 1/41, Praha2
Skupina:	František Jelínek, Pavel Běloušek
Datum:	6.3.2014
Obrázek, pohled (fotografie, výkres pohledu nebo google maps atp.):	
Doba výstavby objektu:	1927
Celková podlahová plocha[1]:	2522,7 m^2
Kulturně historická hodnota	
Architektura objektu v kontextu doby vzniku a jeho významnosti v současné době:	Objekt se nachází v památkově chráněném území Praha 2 – Vinohrady. Samostatný objekt není historiky cenný. Z vnějšího vzhledu stávajícího stavu objekt neobsahuje neobvyklé architektonicko-historické prvky, které by bylo nutno zachovat. Dle původní projektové dokumentace objekt obsahoval historicky cennou fasádu, která se do dnes nedochovala.
Definice cenných prvků a architektonických kvalit, které vyžadují ochranu	Zdobné pásy kolem okenních otvorů. Zachovaní horizontálního členění (římsy).
Kategorie budovy[2 3]:	☐A. Budova bez rozeznané kulturně-historické hodnoty ☐B. Budova kulturně-historicky cenná (nechráněná) nebo budova v ochranném pásmu památky/zóny/rezervace ☒C. Budova v památkové rezervaci nebo zóně ☐D. Národní kulturní památka, nemovitá památka[4]

[1] Dle definice ze slovníčku pojmů SBToolCZ.
[2] Definice památkově chráněných území: http://www.npu.cz/pro-odborniky/pamatky-a-pamatkova-pece/pamatkovy-fond/pamatkove-chranena-uzemi/

[3] Památková rezervace a zóny v Praze. Prostudujte si textovou část, a to především Články 2, 3 a 4, které pomohou s ohodnocením kulturně historické kvality a definují možné stavební zásahy: http://pamatky.praha.eu/jnp/cz/pamatkovy_fond/pamatkove_chranena_uzemi/index.html

[4] http://www.npu.cz/pro-odborniky/pamatky-a-pamatkova-pece/pamatkovy-fond/narodni-kulturni-pamatky/

Figure 3 Form for the assessment of cultural-historical value.

The evaluation of cultural historical value is being done by the assessor (architect) and has to be verified the same way as the whole reSBToolCZ certificate. It has a specific form (Figure

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3) and the building has to be classified according to the heritage protection practice in the Czech Republic into one of these categories:

A. Building without recognized cultural-historical significance.

B. Building culturally valuable but not protected by law; building in a protection perimeter.

C. Buildings in a reservation or a zone.

D. Architectural monument.

These categories represent the level of cultural-historical value of buildings. Buildings that belong to the category A are always assessed with the same benchmark setup as new buildings. Buildings that belong to categories B, C and D use for specific criteria (Table 2) the benchmark setup by the improvement potential.

2.2 Assessment variants

All 11 buildings were assessed in three variants:

1. **Current state** before renovation. Exisiting building was assessed in all criteria. The current state always meant a building without any thermal insulation on façade or advanced energy systems.

2. **Real renovation**. This renovation corresponds to widespread building practice. Usually it means thermal insulation on façade where possible, changes of windows and improvement of heating system is necessary.

3. **Best available technique** renovation (BAT) – represents the best building practices regarding thermal insulation of the envelope, energy systems or green facades.

This resulted into 3x11= 33 assessments in total in 13 criteria described in Table 2.

3 Results

3.1 Assessment of building stages

	Current state	**Real renovation**	**BAT renovation**
Branická 1242	1,5	3,2	6,6
Ječná 29*	0,5	3,8	6,2
K lukám 646	1,7	5	5,9
Moravske Budejovice - Chlečického ul.	0,5	5	7,9
Na Zatlance 8*	1,1	5	6
Nad Královskou oborou 171*	1,5	6,2	8,1
Nuselská 29	2,3	5,4	6,8
Pod sídlištěm 195	1,1	6,9	7
Rubešova 1*	1	7,1	7,4

Ruská 745*	1,6	6,5	5,9
Trojanova 337*	1,1	2,8	6,7
AVERAGE:	**1,3**	**5,2**	**6,8**

**Buildings with cultural-historical value*

Table 4 Buildings and results of their assessment in group of environmental criteria (scale from 0 to 10, 10 is the best)

Results of the assessment indicate that:

- The quality of existing buildings measured by SBToolCZ environmental criteria is generally very poor in current state. We have to keep in mind that we are talking about buildings 30 years old and more.
- Majority of existing buildings can be improved to a level in which their environmental performance is very good and comparable to a new environmentally optimized building.
- This approach shows that reSBToolCZ is an appropriate methodology and assessment tool for decision making process in preparing building investments and measuring quality of their variants.

4 Discussion

However the assessment tool for existing buildings and their renovations might be used in the decision making process, the main challenge for reSBToolCZ and its usage in building practice in general is the lack of involvement of financial aspect of the renovations. There is no general way how to implement financial aspect of particular renovation variants into the assessment even though the investors demand it.

Czech market uses multicriterion assessment tools for buildings primarily as a marketing tool and the sustainability issue of them stands a little bit aside. Sustainability as a public interest is is not yet officially supported by the government in building practice by these assessment tools so they are still only voluntary even for public owned and state owned buildings.

5 Acknowledgements

This work was supported by:

- OP RDI project No. CZ.1.05/2.1.00/03.0091 – University Centre for Energy Efficient Buildings (UCEEB, Czech Technical University);
- European project EURL3a (EAC-2012-0600, European Real Life Learning Lab Alliance);
- Faculty of Civil Engineering, Czech Technical University in Prague.

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6 References

Vonka, M. & et al., 2013. SBToolCZ pro bytové domy. Praha: České vysoké učení technické v Praze, Fakulta stavební

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Energetic and comfort benefits of composite buildings: Learning from vernacular techniques

Speakers:
Szkordilisz, Flóra [1]; Heeren, Niko [2]; Habert, Guillaume [3]

[1] Department of Environmental Economics, BME, Budapest, Hungary
[2] Chair of Ecological Systems Design, ETH Zurich, Switzerland
[3] Chair of sustainable construction, ETH Zurich, Switzerland

Abstract: *Most LCA studies lately have been dealing with the dilemmas which material is more energy-efficient to use: wood or steel, concrete or wood? Unlike to this perception this project takes the idea of Mediterranean vernacular architecture where it has been a tradition for long centuries to compose different – heavy and light-weight – materials in one building. We use Life Cycle Assessment and thermal numerical simulations to compare five houses, built either exclusively with one material or having both materials, either one at the ground floor and one in the first floor or one in all southern façades and the other in the northern walls. Our results show the interest of having massive and light-weight material located in two different places in the house. Especially in the Mediterranean climate it allows an optimal use of the space throughout the year.*

Keywords: Comfort zone, building materials, LCA, climate change

1. Introduction

According to European Union Directive "Energy Performance of Buildings" by 2020 "nearly Zero Energy Building" has to be a norm in all EU countries, which is a significant and ambitious challenge for all member countries [1]. However, in order to be able to propose resilient initiatives, we have to consider that energy savings have also to be combined with adaptability to climate change, as recent IPCC report shows clearly that built environment will have to face more and more frequent extreme summer heat events [2]. Fulfilling these two requirements, of a minimum energy requirement for construction and operation as well as a high adaptability to climate change, is a major goal of the European Union.

But at the same time the fact has to be faced that in order to aim energy efficiency the amount of embodied energy is growing parallel, as embodied energy can represent from 20 to 40% of the total energy consumed during the lifetime of the building [3]. Thus the perspective shifts from the energy consumed during the operation phase to the energy used to produce materials to be used in construction. The mentioned tendency can be seen in the numerous researches in the field of optimisation of material use [4].

One of the best tools to investigate this necessary balance between construction and operation of buildings is the Life Cycle Analysis (LCA) [3]. With LCA, it is possible to show the advantages and disadvantages of using concrete or wood in structures [5]. However the detailed study of Mediterranean vernacular architecture shows that materials are not used separately but rather combined at the scale of the building [6]. In the vernacular architecture of Mediterranean mountain areas – mainly former Osman territories, such as nowadays Turkey, Bosnia, Albania, and Greece –there is a tradition of composite wood and stone buildings: the ground floor being built with thick stone walls, while the southern façade in the first floor is made with a wooden structure [7].

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In the present study we investigate the effectiveness of this method used in vernacular architecture from both energetic and indoor thermal comfort point of view and we evaluate how this technique could be applied in other European regions where climate will become warmer and with higher frequency of extreme events. The objective of this paper is then to study in detail the potential interest of combining material at the house scale.

2. Methodology

2.1. Description of the house designs

In order to investigate the effects on energetic performance and indoor comfort of the usage of different materials we propose five different variants of an ideal house. The design principles for the ideal house were the following:

- to make possible flexible use and changing functions according to the seasons
- In winter, it is decided that just the ground floor will be heated.
- Buffer rooms are located to the north of the house.
- The kitchen situated in the winter zone.
- As we studied vernacular architecture, it is also decided not to use cooling system will be used.
- Openings are designed to enable natural ventilation

The design of the house is presented in *Figure 1.*

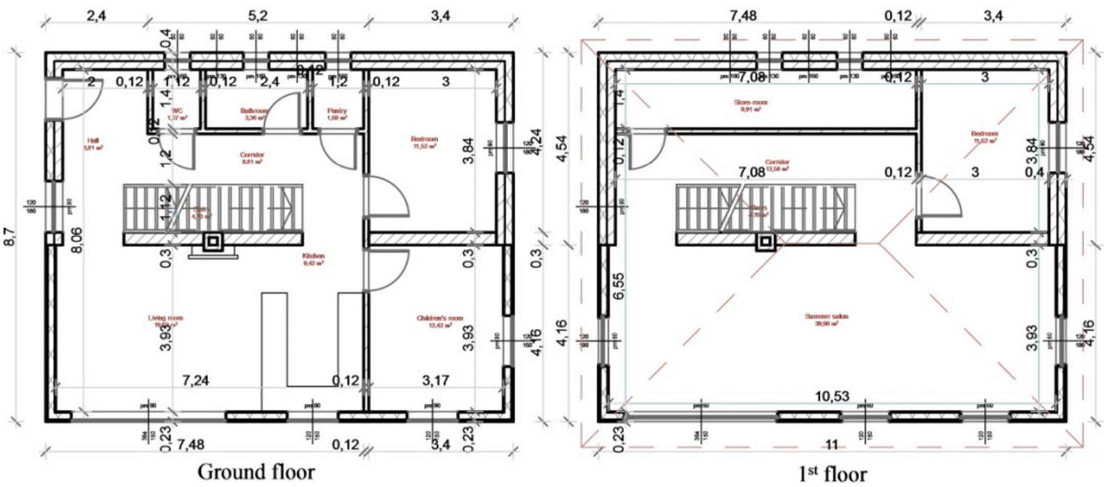

Figure 1: Layout of the house. The position of the materials is changing depending on variants but not the size and organisation of the house. In this variant, North faces are made of concrete and Southern facades are of wood.

The five variants analysed from thermal comfort, energetic and LCA aspects were designed in a way to demonstrate the differences between heavy, lightweight and hybrid structures. The first and second variant (in the following Model 1 and 2) is built with the exclusive use of heavy (reinforced concrete) or lightweight structures (wood). The remaining three variants are

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designed with the combined use of both mentioned materials: in case of Model 3 the building envelope in the ground floor is made of insulated concrete and on 1st floor is made of insulated wood. Model 4 is using heavy materials on the north side and light materials on the south side of the house. The fifth variant (Model 3 mod.) is a modified version of the Model 3 using uninsulated wood structure in the 1st floor.

2.2. Description of heating scenarios for thermal simulation

Thermal simulations were made with Lesosai 7.4 software, using the SIA 2044 algorithm [8]. The software enables to calculate energetic performance and thermal comfort in various zones within the house. Furthermore, it provides hourly results for the whole year. Indoor comfort was defined with a loose interpretation of European norms [9,10]:

$$18°C < operative\ temperature < 27°C,$$

For simulation three heating scenarios were used on each model.

- not heated: none of the zones are conditioned. All models are investigated under free-floating conditions to see the effectiveness of passive solar heating in each model
- all heated: All zones are heated. All models were analysed in heated case also, in order to evaluate energetic performance of each variant and to have a reference for comparing comfort hours too.
- lower part heated: the idea mimics the usage of traditional dwellings, where it was common to occupy the heated downstairs part of the building during the winter and to move to the unheated lightweight structure in the upper part of the house.

In structure design three types of walls were used: insulated concrete, insulated wood, and uninsulated wood. The insulated concrete wall has 20 *cm* reinforced concrete and 20 *cm* insulation on the outer side. U-value is: 0.18 W/m^2K. Insulated wooden wall has 16 *cm* insulation so the U-value is 0.18 W/m^2K too. In the 'Model 3 mod' an uninsulated wooden structure is used which's U-value is 1.417 W/m^2K. (See *Figure 2.*)

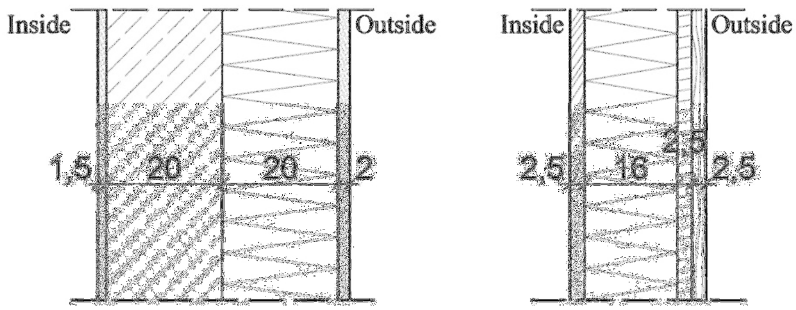

Figure 2: Layer structure of the two types of walls used in modelling

The heating scenarios listed already imply also the usage scenarios suggested. Nowadays designers consider a house usually appropriate for permanent residence, even if it is used only in a part of the year. Opposite to this concept the usage scenario we suggest, is based on the dwellers diverse expectations and habits in winter and summer. In winter inhabitants spend

most of their free time indoors, so a pleasant thermal comfort is required and thinking of structures there must be a possibility of passive utilisation of solar energy. On the other hand in summer people spend most of their free time outdoors, and it is more important to provide shelter during the day and a cool indoor climate during the night. One can easily see that these two tendencies need different structures for realisation. While it is advantageous to have big thermal mass and good insolation in the winter, in summer it is more effective to have light structure in order to facilitate quick cooling after sunset. Of course that's means that zoning is needed while planning the house and different zones are used under different meteorological circumstances. One could think for the first sight that this means a loss of the really usable area of the house will see that it has also advantages. This is the idea Mediterranean vernacular architecture was based on and this is, which energetic effectiveness we should like to prove next.
For thermal simulation the meteorological data of Volos, Greece were used. If heated, heating temperature in living- and bedrooms is *20°C*. For the calculation of comfort hours the hourly results of operative temperatures were used as operative temperature represents more relevant the human comfort as air temperature. (In the case of only ground floor heated the comfort data of the non-heated case were imported for the 1st floor.) The software gives hourly results for a whole year to be able to sum up the number of indoor comfort hours.
Parallel with the indoor comfort energy demand of heating was calculated too – also on the base of hourly results given by the software.

3. Results

3.1. Results for all simulations

A short résumé of the most important results is seen in *Table 1*. In the columns you see the models listed (with comfort hours per year and heating energy consumption if heated). In the rows data are classified by heating scenario.
These results show clearly the advantage of heating the lower part of the house in winter. Whatever design is used, the number of comfort hours in the lower part is moving from around 3'000 to 8'000 hours. However, the interest is of course less clear in summer as no cooling system was used. Therefore allowing heating in the lower part increases the number of comfort hours from around 1'000 hours during the cold summer nights. Concerning the upper part, similar conclusion can be drawn. It is still interesting to note that heating the upper part actually reduces the number of comfort hours in the lower part, which reduces the interest of having both zone heated and somehow justifies the traditional organisation of the house where the heating source was only localised in the lower part of the house. In the following results we will therefore only consider the simulations where the lower part of the house is heated allowing to use it during all winter and to use the upper part most of the days in summer and some warm winter days.

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		Model 1		Model 2		Model 3		Model 4		Model 3 mod.		
		Comfort hours [h/year]	energy demand [kWh/m^2 year]	Comfort hours [h/year]	energy demand [kWh/m^2 year]	Comfort hours [h/year]	energy demand [kWh/m^2 year]	Comfort hours [h/year]	energy demand [kWh/m^2 year]	Comfort hours [h/year]	energy demand [kWh/m^2 year]	
Not heated	***Upper part***											not heated
	Summer	*1942,5*		*1485*		*1485*		*1451*		*2279*		
	Winter	*1599*	n.a.	*1519*	n.a.	*1519*	n.a.	*1422*	n.a.	*856*	n.a.	
	Lower part											
	Summer	*1760,5*		*1274*		*1761*		*1262*		*2147*		
	Winter	*1840*	n.a.	*1335*	n.a.	*1840*	n.a.	*1226*	n.a.	*1404*	n.a.	
Heated downstaires	***Upper part***											
	Summer	*3885*		*2970*		*2970*		*2902*		*4557*		
	Winter	*3198*	n.a.	*3037*	n.a.	*3037*	n.a.	*2843*	n.a.	*1711*	n.a.	
	Lower part											heated
	Summer	*2434*		*1572*		*2434*		*1674*		*2460*		
	Winter	*4368*	**41,52**	*3800*	**33,72**	*4368*	**46,37**	*3800*	**34,10**	*4368*	**44,94**	
Heated all	***Upper part***											
	Summer	*1975*		*1658*		*1658*		*1724*		*2349*		
	Winter	*4121*	**33,39**	*3582*	**26,67**	*3582*	**26,67**	*3582*	**28,89**	*4282*	**155,44**	
	Lower part											
	Summer	*1990*		*1390*		*1990*		*1494*		*1990*		
	Winter	*4243*	**32,91**	*3225*	**26,34**	*4243*	**32,91**	*3225*	**29,40**	*4243*	**32,91**	
Embodied energy	*GWP [kgCO$_2$/ year]*	**166**		**20**		**96**		**100**		**94**		
	NRE [MJ/ year]	**1611**		**412**		**1040**		**1067**		**991**		

Table 1: Results of thermal simulation for all five variants. Number of comfort hours in h*, space heat demand in* kWh/m^2*year*

3.2. Comfort hours during summer for the five variants

Let's now consider the choice of the five variants, during summer, when only the lower part is heated. The lower part can be used most efficiently either in the model design 1, 3 or 3 modified, which means when a massive and insulated structure is used all around the house. Model 2 (made of wood) or Model 4 (made partially of wood and concrete) have actually around 1'000 less hours of comfort in the lower part than the other models (*Table 1.*). No significant differences can be seen between the three models with concrete on the lower part, which is obvious as they have all the same design on the lower part. For the upper part, large differences can be seen between models. We can see a clear advantage of having a wood non insulated structure in summer compared to the concrete or the wood insulated first floor. It is also clear that the hybrid structure where wood and concrete are combined in both floors (Northern façade in concrete and southern façade in wood) provides the lowest amount of comfort hours during summer.

3.3. Environmental impact vs available space

To be able to distinguish the three variants that seem to be the most advantageous, we considered the embodied energy on materials. It is clear that a house made of wood has a significant consumption of non-renewable energy for the production of the building materials

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than a house made only in concrete. Furthermore, the three variants where wood and concrete are combined have similar environmental impact, as the position of the material doesn't change the embodied energy and that the major impact comes from the structural materials and not from the insulations materials (the upper part insulated or not does not change the embodied energy of the house). The *Figure 3* shows the results for the 5 variants in term of embodied energy and available space in summer. The available space is being calculated by multiplying the number of comfort hours of both part of the house by the size of the floors.

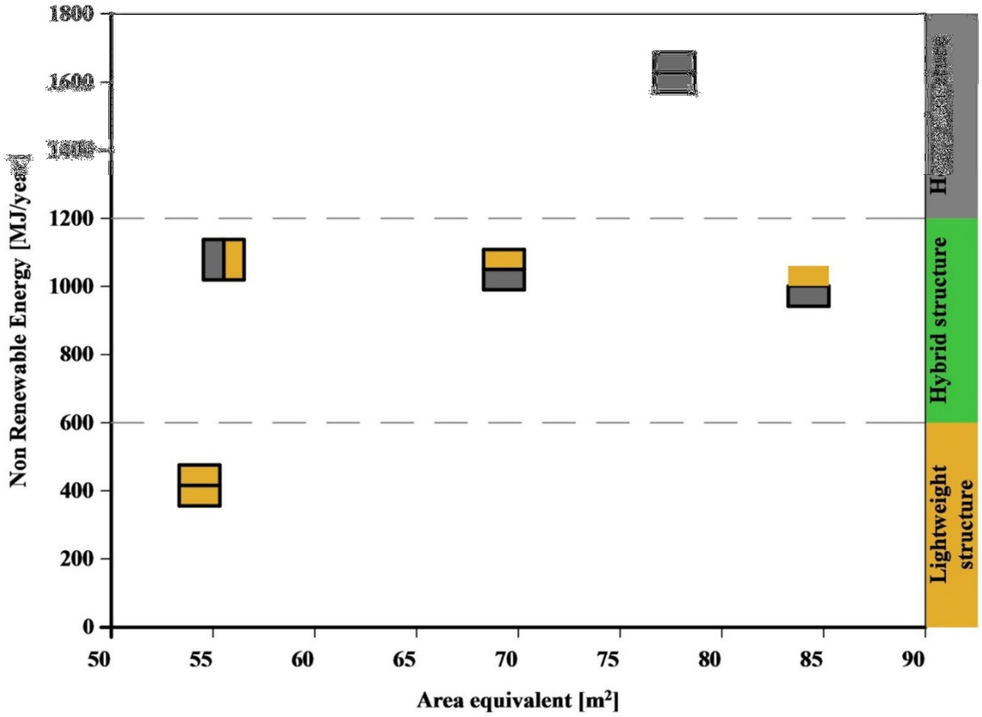

Figure 3: Available space for the five different variants in summer. (Down part is heated) Y axis shows the embodied energy, X axis shows the area equivalent which is calculated:

$AEQ[m^2] = \frac{CH_{up}[h]}{365\times 24\,[h]} \times A_{up}\,[m^2] + \frac{CH_{down}\,[h]}{365\times 24\,[h]} \times A_{down}\,[m^2]$*; where*

AEQ: area equivalent; CH_{up}: summer comfort hours upper part; A_{up}:area upper part; CH_{down}: summer comfort hours down part; A_{down}:area down part.

In the *Figure 3*, it becomes clear that there is a need for lower massive part in the house and that an upper non insulated wood structure provides the higher amount of space usable in summer. The *Figure 3*also illustrates very clearly that: 1) Only lightweight structures are not sufficient to achieve a large amount of comfort hours (even in summer). 2) Massive structure has an interest to provide a large amount of comfortable space, but it is made in detriment of the large embodied energy consumed. 3) Hybrid structures allow a good compromise in term of embodied energy between massive and light structures. 4) Depending on how this hybrid structure is designed, the available space can be as good and even better as the fully massive structure.

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4. Conclusion

In this study, we have shown that hybrid design allows providing the highest amount of available space with a lower embodied energy than massive structures. Furthermore, it seems clear that not all hybrid designs are interesting but that only one specific is particularly adapted. Having a heated ground floor of massive structure and an uninsulated non heated upper floor is the best compromise in term of embodied energy, heating demand and indoor comfort.

This system is actually the one used in vernacular architecture of Mediterranean regions. Compared to massive concrete houses that are now built in these areas, it is interesting to note that the number of comfort hours is not different (if not a little bit lower), but the embodied energy is twice bigger.

5. Bibliography

1. 2010/31/EU (2010) – Energy Performance of Buildings Directive recast, DIRECTIVE 2010/31/EU of The European Parliament and of the Council, of 19 May 2010
2. IPCC, (2013): Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp
3. König, Holger, De Cristofaro, M. Lisa, (2012) Benchmarks for LCC and LCA of residential buildings. Building research and information. 40, 558-580. doi: 10.1080/09613218.2012.702017
4. Kellenberger, Daniel, Althaus, Hans-Jörg (2009) Relevance of simplifications in LCA of building components. Building and Environment, Volume 44, Issue 4, 818-825, doi: 10.1016/j.buildenv.2008.06.002
5. Dodoo, Ambrose, Gustavsson, Leif, Sathre, Roger (2012) Effect of thermal mass on life cycle primary energy balances of a concrete- and a wood-frame building Applied Energy, Volume 92, 462-472, doi: 10.1016/j.apenergy.2011.11.017
6. Dimitris Filippidis (1995) Elliniki Paradosiaki Arcitektoniki, Tomos Ektos, Thessalia – Ipeiros, Athens, Ekdotis Melissa, pp. 11-71,
7. Evangelos Evangelinos (2003) Thermal Comfort in Greek Vernacular Architecture – An Interpretation of the Building Shell, pp. 47-52 in: Edited by Dimitra Babalis: Bioclimatic Design & Urban Regeneration, Firenze, Editioni Polistampa
8. SIA2044 Standard (2010) Klimatisierte Gebäude – Standard-Berechnungsverfahren für den Leistungs- und Energiebedarf, Schweizerische Ingenieur- und Architektenverein, SIA Zürich
9. EN 15251 (2007) Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics. CEN, Brussels.
10. SIA 382/2 (2011) Klimatisierte Gebäude - Leistungs- und Energiebedarf, Schweizerische Ingenieur- und Architektenverein, SIA Zürich

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Vernacular Architecture Approach to achieve sustainability In Informal Settlements

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Abstract: *The extension of informal settlements in urban regions all over Egypt is one of the most crucial threats to the quality of life on social, economic and environmental levels. Of particular concern are the current alarms caused by informal extensions of residential communities in several arid areas such as Siwa and El-Dakhleh Oases is in Egypt. In most cases intrusive reinforced concrete unfinished blocks are condensed to shape informal spots throughout the built up environment. However, the characteristics of the local architecture, imbedded in such areas are shaped by local citizens to mirror their social, culture and aesthetic values. Meanwhile, primitive environmental concerns are explicitly reflected through the use of natural resources, local materials and building technologies. This study highlights the potential benefits of adopting aspects of vernacular architecture in allowing a higher and more sustainable quality of life in the residential communities of arid regions in Egypt. The study discourses how to achieve sustainable development of informal communities in accordance with the indigenous features of the local architecture of the arid region. The study aims to employ values of vernacular architecture in developing agendas for dealing with the informal settlements to provide sustainable communities.*

Finally, the study will give some recommendations to help maintain the value of the vernacular architecture of these regions and distinctive social values, culture and their own aesthetic and sustainable development of those communities.

Keywords: Vernacular Architecture, arid regions, sustainable development

1-Introduction:

The extension of informal settlements in urban regions all over Egypt is on the rise and continues to deteriorate despite some attempts to stop this extension. This is due to the disability of understanding these communities and thus the way to development them culturally, socially and economically. These communities represented by the customs and traditions inherited in them can be understood through their cultural assets and social values inherent in the Egyptian society in general. This can be clear when noticing how these values appear in the arid desert communities and thus reflected in their environment.

Since the informal settlements in Egypt consist of a group of individuals displaced from regions such as arid desert and rural areas- in pursuit of higher incomes and higher education in urban cities- these families have different customs and traditions, but the nature of Egyptian social genes helps in melting those differences and this is quite evident in old informal settlements that has been formed in a period of not less than thirty years. Sustainable development may represent the best solution to upgrade those settlements and preserve the vernacular architecture in Egypt.

2-Vernacular architecture in Egypt:

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To derive the main items of the practical part of the research, the study will describe and analyze the vernacular Architecture in Egypt through three different categories; rural regions, arid regions and informal settlements. In each category elements and composition of forms of the vernacular houses would be studied.

2-1-Vernacular architecture in rural regions of Egypt:

Vernacular architecture in rural Egypt stretches on the banks of the River Nile, it used to mainly consist of one to two floor buildings made of clay, those buildings were houses for the poor peasants as shown in fig (1). After the 1952 revolution, changes occurred due to the nationalization which led to the acquisition of land from the original owners and its division into five acres for each farmer, after generations areas of land were distributed among those who inherited them into smaller plots- depending on the number of family members which were 6 in average- and with the new policy of free education then, most of the youth sought education and thus neglected working in agriculture and eventually sold their share of the land. Fragmentation of agricultural land and lost identity of rural Egypt, in addition to the absence of censorship and encroachment on agricultural land turned a lot of agricultural land to random residential areas and buildings of concrete and red bricks, this had an impact on poorest areas which were far from any urban areas, especially in Upper Egypt, such as the Nubian region, which was once the area that took the attention of the famous Egyptian architect Hassan Fathy, and through years of his study gained his unique architectural experience.

Fig (1). Form rural region of Egypt.

www.aawsat.com

Hassan Fathy, despite his knowledge of new architectural trends in the fifties, he preferred to focus on his country Egypt through authentic thoughts and approaches. With his statements Sayings that he assesses the heritage and it is connected to the present 1, saw that the Nubian region in Upper Egypt by virtue of geographic isolation , has been able to maintain its character and authenticity. On the other side such originality have been lost in major cities and in rural areas in Lower Egypt and on its way to the desert areas of heritage value. The values can be clearly distinguished in those Nubian isolated communities due to the lack of any imported cultures. Hassan Fathy believes that the architect must be familiar with all the values and cultural traditions of this community, he does not imagine that there is a separation between the architect and the man who builds it, the architect only helps in the architectural culture within the provided means.[1]

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Fig (2).Nubian region in southern Upper Egypt. (www.shutterstock.com)

2-2Vernacular Architecture in arid communities

Western Desert of Egypt is in fact part of the arid Sahara and in relative to the area of Egypt which is one million km2, it represents more than two-thirds of the total area. The western desert although barren, but it comprises a number of oases containing lakes and fertile areas resulting in the fruits of Egypt's best and greatest wealth and these emerging areas are : El-Dakhla, El-Farafra, El-Baharia and Siwa Oasis, as shown in Figure (3).

Fig (3).Siwa Oasis Arid región in Egypt.[2]

It can be deducted that there is environmental similarities between both El-Kharga and El-Dakhla regions and also between Sohag and Qena, but as for Nubia in upper Egypt, it is different with a unique character due to its geographical isolation and its direct location on the Nile. As for El-Farafra and El-Baharia they are quite similar to Fayoum, Minya, Assiut regions,and thus Siwa Oasis may be regarded as an independent region different in natural and man-made environment, resulting in a unique planning and urban pattern from all Egyptian oases, as it shows us how spontaneous these patterns with the natural environment, such as using natural building materials as Karshef which is a soil used mixed with gypsum and salt (sand and silt and salts). Today, the existing and remaining desert vernacular architecture in remote communities and settlements in Egypt is about to vanish. There is limited documentation and listing efforts by local authorities. Traditional desert vernacular settlements are being abandoned, and are deteriorating and/or are being demolished intentionally or unintentionally.[3]

One cause of this dilemma lies in a currently adopted norm by some dwellers, especially youth who have an overwhelming desire to adopt a modern lifestyle that reflects their need to attain a better living condition with better facilities where the majority of their vernacular dwellings sometimes do not currently fulfill such demands in the way these young people want. However, by entering the stream of urbanization and absorbing westernized concepts, people greatly endanger the continued existence of ethnic desert vernacular architecture in the desert oases in Egypt. There is a change in the appreciation of traditional values which is

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reflected in new views among people in desert areas about how they want to live. It might be argued that these changes are now harming the desert vernacular architecture and traditional structures in Egypt .[4]

Fig (5).[6]

Desert vernacular settlements in the Western Desert of Egypt were facing dramatic problems. Inhabitants in desert vernacular dwellings, for example, are leaving their houses to deteriorate and moving away from their old towns and villages. Others demolish their vernacular dwellings and replace them with houses made from artificial building material. In some parts of the Western Desert, a tendency has been noted for inhabitants to change their lifestyle-moving into concrete houses or demolishing their traditional ones without a keen sense of adaptation to change or respect for the inherited values of the traditional Egyptian dwellings.[6]

2-3Vernacular architecture slums Egypt's urban:

The phenomenon of informal settlements started to appear in Egypt mid-1950s as a result of different policies that Nasser's government , till the fall of Mubarak –25th January 2011 adopted and caused informal housing phenomenon. The different policies laws and legislations that were passed over the past 60 years greatly affected the housing sector. Starting in 1980, the government launched a programmer to improve informal or slum areas throughout Egypt. In Greater Cairo a total of 81 slum areas were identified, of which 63 upgradable, others slated for demolition and resettlement of their inhabitants.7

There have been negative changes in the development of buildings against their environment. With the increase in the accumulation of those concrete housing units and their vertical extension and lack of control, not only in cities but in villages, especially those adjacent to the cities, a far cry from the concept of sustainability and lost many of the general principles of the concept of vernacular .Building became not just erratic but lost their Egyptian Architecture identity and their social and cultural character as well.

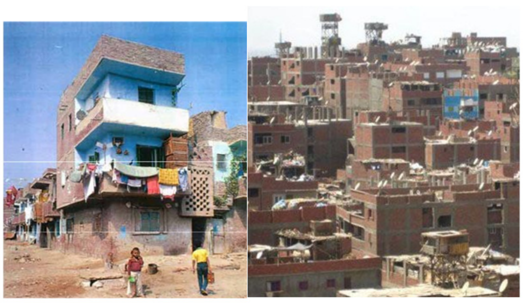

Fig (6). Ministry of Local Development 2001.

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These regions may not provide the minimum basic needs for an acceptable standard of life for people, especially in the aspect of social behavior that is the concept of sustainable development. Hence, it is not acceptable to refer to those informal settlements /slums in Egypt as vernacular. The definition of "vernacular" according to the views of specialists, such as Paul Oliver who defines the term as follows: “Vernacular architecture comprises the dwellings and other buildings of the people. Related to their environmental contexts and available resources they are customarily owner- or community-built, utilizing traditional technologies. All forms of vernacular architecture are built to meet specific needs, accommodating the values, economies and ways of life of the cultures that produce them" or Baker who say’s that the folk tradition is much more closely related to the culture of the majority and life as it is really which represents the culture of the elite. The folk tradition also represents the bulk of the built environment. Rapoport.Vernacular architecture is congenial to people and sympathetic to environment. Bruce Allsopp.5According to table 1, the research finds that the most agreed items are discussed in the following: The regional forms, materials and technology- Forms that reply to specific needs of human- Forms that reply to the values, economics, and way of life of certain culture- Dwelling buildings as the major representation of vernacular architecture. [5]

The items of vernacular architecture form that the definitions concentrate on them

The definition of vernacular architecture by	The regional forms, materials, technology	Forms that reply specific needs of humans	Vernacular as a culture of the majority of people	Forms that reply the values, economics, way of life of certain culture (people)	Vernacular forms as norms that have been accepted by people	Variation in models and few types	Vernacular architecture with no theoretical background	Vernacular dwellings
Oliver								
Rapoport								
Baker								
Porter								
Allsopp								

Table (1). 5

3- Vernacular architecture and its relation to sustainability

The sustainability of Vernacular Architecture is also about managing the balance between preservation and use. Arid and rural vernacular dwellers show multi-layers of wisdom in their use of the limited local materials, the minimum waste of such resources and an ability to be inspired by forms from nature. In addition, from an economical point of view, such local building materials are almost cost-free, as locals use wood trees and palm trees grown on their farmlands, and cast mud bricks using earth from their surroundings. People build their own dwellings, so there is almost zero labor cost. The possibility of re-using the earth material is another aspect of sustainable desert vernacular. Almost no waste product is produced from desert vernacular buildings.

According to the issue of sustainability, with two different attitude to technology to achieve this ultimate aim, Le Corbusier refers that the harmony could be created by using the modern technologic advances which at the same time had socially corrective potential. Thus he was apt to realize the harmony through the combination of indigenous architecture and the modern

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technology. HassanFathy felt that technology should be subservient to social values, and appropriate to popular needs. He found the truest expression of technology in vernacular architecture as he believed that it had solved the function problems with the available material and least energy consumption. The vernacular technology stood f or the hundred years' test and was fundamentally suitable for the climate and local economy and social conditions. Although Fathy used traditional elements in his work, he did not intent to just make copy of the work of the past. His new forms were the adaptations of the prototypes. The sustainability can only consist in the utilization of appropriate technology. [8]

4-Balat the Vernacular desert town-Western Desert oases, Egypt:

This chapter presents the analysis of the case study carried out in the town of Balat.
Balat vernacular will be described in terms of architecture and of urban and building technology. Some factors are relevant to social, cultural and economic analysis will be introduced as well.Balat still maintains its cultural and historical identity, and its potential for future development. From the point of view of aesthetics and form, Balat can be considered a distinctive piece of sculpture, characterized by a highly distinctive aesthetic architecture appearance. Hassan Fathy has considered Balat to be the bride of the desert. Buildings there are like carvings done by sensitive thinking hands that curve every piece to function in a certain way.[6]

Fig (7). Typological architectural formation of dwellings in Balat. Inhabitants adjusted local materials to the purpose of connecting houses.[6]

The design and construction process in itself is simple and clear, although the final result might be complex when built in a vernacular fashion. The process begins with a mason builder being called in. His experience and detailed knowledge of building rules is needed to start the work. Since everyone has a general knowledge of these rules and steps, the family and the builder discuss together issues such as the size of the house, the layout, the relation between the house and the street, together with the site. Inhabitants participate not only in the design of their house but in the building process as well.[6]

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Fig (8). Semi shaded road & House facade in Balat.[6]

In Balat, as in all desert societies, the basic social unit is the extended nuclear family.Balat inhabitants tend to live in extended–family compounds. Families may comprise married couples and their children, and may also include grand-parents, as well as brothers and sisters of successive generations. Family members live with separate sleeping, kitchen, and leisure spaces facing a common open area.[6]

5- Conclusion:

Arid areas - authentic by past values - must be developed and returned to the philosophy of the ancient Egyptian home which provides privacy, reflects awareness of thermal environmental design, respects family ties within the house along social ties within the community and uses local building materials which commensurate with the nature and atmosphere of the place, and preserves the future of the desert vernacular architecture on a collaborative basis with the residents. Re-thinking in the context of contemporary architetcure is still related to low environmental costs and benefits, as well as the picturesque exterior vernacular architecture of the desert.

Sustainable design balances human needs (rather than human wants) with the carrying capacity of the natural and cultural environments. It minimizes environmental impacts, and thus minimizes the import of goods and energy as well as the generation of waste. Besides the environmental response to the local climate and geography, vernacular also enhances a feeling of community. The desert vernacular buildings should not only be seen as charming reminders of an era that is gone but that they are a record of a lifestyle, tradition and culture.

6- References:

1- Hassan Fathy. (1997),An Architecture for people, University of Michigan.
2- Siwa- homes (2009).jpg, Wikipedia.
3- حاتم الطويل (1988) البيئة والعمارة في سيوة ،رسالة ماجستير في العمارة، جامعة حلوان، مصر.
4- Francesca De Filippi, (2006),Traditional architecture in the Dakhleh Oasis, Egypt: space, form and building systems.
5- Khayat, Mahmood. (2009) Formal characteristics of vernacular architecture in Erbil city.University of sallahaddin, Erbil.
6- Marwa Dabaieh, (2011), A Future for the past of desert Vernacular Architecture, LUND University.
7- Mohammed Alfiky, (2010), Informal settlements'phenomenon as a result of Egypt's policies,"GCR" (ISDF).

8- Vernacular Precedent adaptation in design in terms of sustainability,Master of Arts (Architecture), National University of singaphore, 2005.
9- Paul Oliver, (2006),Built to Meet Needs, Oxford.
10- Lindsay Asquith, (2006) Vernacular Architecture in 21Century, Tylor&Francis Group, London and New York.
11- Willi Weder, (2013), Lessons from Vernacular Architecture,Tylor&Francis Group, London and New York.

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Using Historic Cases to Formulate Appropriate Sustainable Building Refurbishment Strategy

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Abstract: *Existing buildings are indispensable in a society and they will continue to exist until they reach the end of their service or economic life. While it is crucial to upkeep existing buildings, enhancing their sustainability is equally important as the energy performance of some older properties is usually less than satisfactory. Despite that, it is never easy for citizens to establish which is the most suitable sustainable refurbishment strategy for their properties. If historic cases can be captured and represented systematically, owners and occupants living in properties of similar types can review the outcomes of these cases to decide whether some sustainable building refurbishment solutions adopted by the others before are applicable to their property. In the paper, a prototype case-based reasoning model for sustainable building refurbishment is proposed. This paper demonstrates how to make use of the proposed model to retrieve and reuse previous cases to derive suitable sustainable building refurbishment strategies for existing buildings.*

Keywords: ***Sustainable refurbishment, case-based reasoning, energy, emissions reduction***

Introduction

Construction facilities are extremely durable and will continue to exist if they are properly maintained (Levine *et al*., 2007). While the values of existing buildings are unquestionable, the energy performance of some existing properties is not comparable to that of the new built in general. Facing the global challenge of climate change, the building sector must react by identifying solutions to reduce energy usage arising from existing buildings (Imboden, 2000).

Hong Kong being a developed economy has a strong demand for electricity. According to EPD (2010), over 90% of various end use of electricity is related to the use of building facilities. In 2009, 37,694 million kWh of electricity was consumed generating a carbon dioxide equivalent of 24.5 million tonnes (EMSD, 2010). Many organisations and citizens aware of the impacts of energy saving and have begun to change their behaviour or replace electrical appliances with the more energy efficient ones.

However, a significant reduction in the carbon footprint of existing buildings necessitates a comprehensive improvement of building components and/or building services equipment in holistic manner (Taylor *et al*., 2010). This is particularly the case for buildings in urban metropolis like Hong Kong as most of them are of multi-storey nature and owned / occupied by different inhabitants. Sustainable building refurbishment should, therefore, be carefully planned so as to maximise the opportunity for emission reduction.

Apart from the technical issues, the support of owners and occupants in multi-storey buildings towards a sustainable building refurbishment programme should not be underestimated as any major improvement works would cost and may affect their daily life. Failing to address the concerns of building owners and occupants could affect the success of a sustainable building refurbishment schemes. However, it is never easy to anticipate the outcomes of a sustainable building refurbishment scheme as every building is unique and the expectations of owners and occupants could be totally different (Egbu, 1997).

The experience gained from previous sustainable building refurbishment schemes could help owners and occupants envisage the potential benefits and pitfalls brought by a potential sustainable building refurbishment solution and hence increase their confidence in accepting a proposal. Case-based reasoning being a modelling approach to remember, retrieve, reuse and revise historic cases for decision support (Aamodt and Plaza, 1994) may have a strong avenue for sustainable building refurbishment decisions.

In this paper, a case-based reasoning model is proposed to assist owners and occupants formulate appropriate sustainable refurbishment strategies. The paper begins by unveiling the characteristics of the case-based reasoning approach. Based on some historic cases, a prototype case-based reasoning model is developed and the features of the case-based reasoning model for sustainable refurbishment are exemplified. The paper concludes with the way forward of the case-based reasoning model for sustainable building refurbishment.

Research Method

The research began with a major literature review to identify the historic cases for sustainable building refurbishment around the world. Through the collected cases, the features in terms of project characteristics, owner / occupant requirements, emission reduction goal, sustainable refurbishment solutions chosen, initial cost, operating cost, effectiveness in energy / emission reduction, disruption to the owner / occupant, etc. can be identified (*cf:* Augenbroe and Park, 2002). Interviews were then carried out to confirm whether the features as identified in the literature are applicable to Hong Kong.

Since the building type and climatic condition of Hong Kong are not the same as other countries, the sustainable building refurbishment solutions could be quite different. Moreover, as buildings in Hong Kong are of multi-storey multi-occupant nature, it is sensible to divide the sustainable building refurbishment options according to different functional areas, e.g. for common areas and residential units. The possibility of applying the identified sustainable building refurbishment options were examined through a questionnaire survey.

The last stage of research involved the development of a prototype case-based reasoning model for sustainable building refurbishment decisions. This involved the design of case structure based on the findings of the preceding stages. With that, the case repository was set

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up by inputting the historic cases into the model. Then, the case retrieval mechanism was devised based on the mega-knowledge and near-match comparison concepts. The output interfaces were designed to allow the users compare the cases and review the case outcomes.

Case-Based Reasoning

Case-based reasoning is an artificial intelligence technique that solves new problems by adapting solutions that were used to solve old problems (Riesbeck and Schank, 1989). Case-based reasoning mimics the way of human problem solving by recalling and adjusting similar decisions made in previous cases. This would not only reduce the time for decision making, it should also prevent the same mistakes from being replicated in the current case.

More important, the case-based reasoning approach lends itself to complex dynamic environment as it allows similar rather than exact scenario be retrieved for decision support. This is particularly relevant to the sustainable building refurbishment problems as the project characteristics and occupant expectations could vary from one case to another. For those reasons, case-based reasoning has been applied to many construction management domains such as architecture design, contractor prequalification, procurement selection, etc.

Through the case-based reasoning approach, the features and outcomes of historic cases are identified and stored in the case repository. When there is a new problem, the characteristics of the new problem will be used to identify similar historic cases. Similar cases will be retrieved and similarity scores will be provided so as to denote the degree of similarity. Users can examine the retrieved cases. In case the cases retrieved are not comparable to the current problem, further retrieval can be conducted until a relevant historic case is identified. Given the retrieved cases may be slightly different from the current problem, adaptation have to be performed to fine-tune the solution in order to warrant the best result.

System Architecture

The proposed case-based reasoning prototype for sustainable building refurbishment consists of five modules namely: input, knowledge and data, case-based reasoning, analytical, and output. The components of these five modules and the relationships between various modules and components are shown in Figure 1.

The data input module allows decision-makers to enter the features of a project as well as the owners / occupants expectations. Once the necessary information is fed into the case-based reasoning module, cases that are similar to the input parameters are retrieved. The sustainable building refurbishment methods used along with the lessons learnt and the satisfaction of the retrieved case(s) are made available to decision-makers for scrutiny.

If the retrieved cases are different from the building in question or if the results of the green refurbishment actions are not as satisfactory as desired, decision-makers can adapt the solutions. Otherwise, they can simply adopt the solutions. Besides, data related to thermal performance and costs along with knowledge on human behaviour and perceptions are stored in the data and knowledge module. Decision-makers can check the results of the cases retrieved against the expected thermal performance of a sustainable refurbishment action.

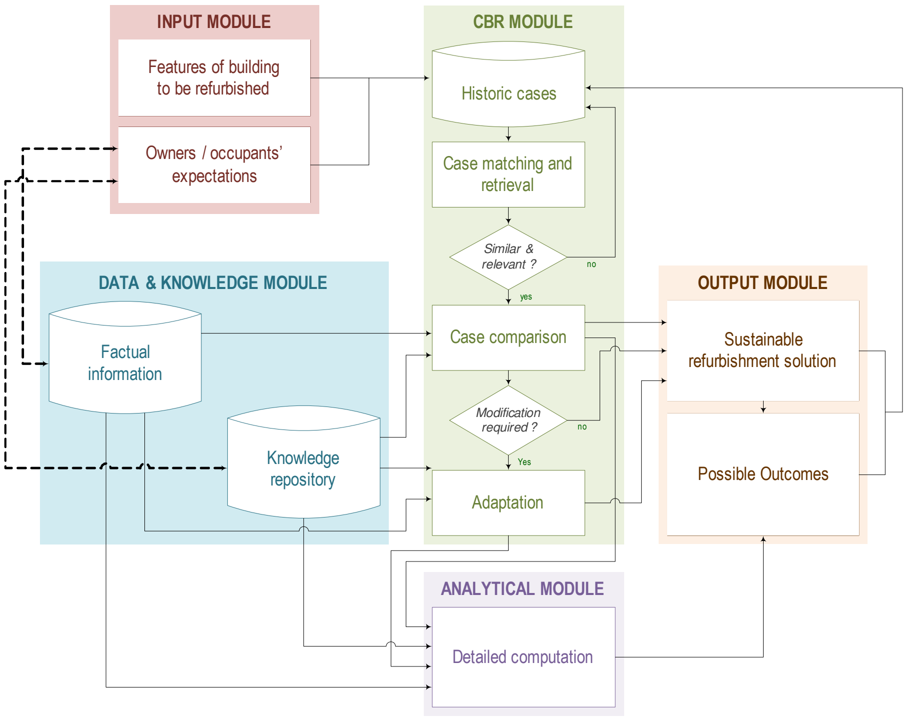

Figure 1: Architecture of the prototype case-based sustainable building refurbishment model

Based on the adopted or adapted solutions and the relevant information and knowledge, detailed analyses are performed by the analytical module to estimate the energy consumption, carbon emissions, and costs before and after the refurbishment is introduced. The preferred sustainable refurbishment solution, amount of GHG reductions, anticipated costs, predicted disruption, and mitigation measures are reported through the output module.

Prototype Case-Based Reasoning Model

The prototype case-based sustainable building refurbishment model was developed using a case-based reasoning tool known as COLIBRI Studio. The reasons for choosing COLIBRI Studio are because it provides the visual builder tools and it is integrated into the popular Eclipse integrated development environment. These should eliminate the tedious work of developing the case matching and retrieval mechanisms.

Using COLIBRI Studio, an interface for users to capture the existing sustainable building refurbishment cases is developed. The features of historic cases including the basic information, pre-refurbishment assessment, refurbishment measures adopted, and the post-refurbishment assessment can be entered through the interface. As shown in Figure 2, a list of possible values is provided under each parameter so as to simply the data entry process. The inputted data is stored in the case-base for subsequent case comparison and retrieval.

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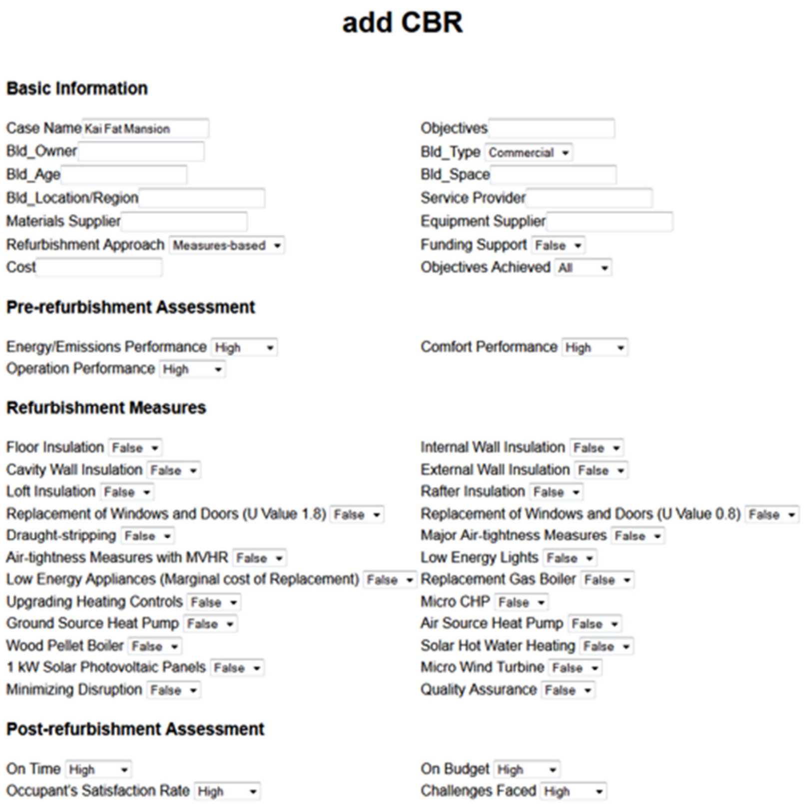

add CBR

Basic Information

Case Name Kai Fat Mansion
Bld_Owner
Bld_Age
Bld_Location/Region
Materials Supplier
Refurbishment Approach Measures-based
Cost
Objectives
Bld_Type Commercial
Bld_Space
Service Provider
Equipment Supplier
Funding Support False
Objectives Achieved All

Pre-refurbishment Assessment

Energy/Emissions Performance High
Operation Performance High
Comfort Performance High

Refurbishment Measures

Floor Insulation False
Cavity Wall Insulation False
Loft Insulation False
Replacement of Windows and Doors (U Value 1.8) False
Draught-stripping False
Air-tightness Measures with MVHR False
Low Energy Appliances (Marginal cost of Replacement) False
Upgrading Heating Controls False
Ground Source Heat Pump False
Wood Pellet Boiler False
1 kW Solar Photovoltaic Panels False
Minimizing Disruption False
Internal Wall Insulation False
External Wall Insulation False
Rafter Insulation False
Replacement of Windows and Doors (U Value 0.8) False
Major Air-tightness Measures False
Low Energy Lights False
Replacement Gas Boiler False
Micro CHP False
Air Source Heat Pump False
Solar Hot Water Heating False
Micro Wind Turbine False
Quality Assurance False

Post-refurbishment Assessment

On Time High
Occupant's Satisfaction Rate High
On Budget High
Challenges Faced High

Figure 2: Capturing an existing sustainable building refurbishment case in the model

Query

clt_Experience	PRIMARY_EXP
clt_Type	INVESTOR
clt_In_house_Capability	true
clt_On_time_Completion	MUST
clt_Within_budget_Completion	MUST
clt_Willingness_to_Take_Risks	false
clt_Trust_in_Others	true
clt_Willingness_to_be_Involved	false
prj_Project_Scale	0
prj_Building_Type	ADMIN_AND_CIVIC
prj_Construction_Type	REFURBISHMENT
prj_Site_Risk_Factors	true
prj_Sophisticated_Building_Services	false
prj_Highly_Aesthetic_Appearance	<any>
prj_Technologically_Advanced_Building	<any>
prj_Lifecycle_Efficiency	MUST
ee_Market_Competition	<empty>
ee_Contractor_Availability	true
ee_Technology_Availability	<any>
ee_Materials_Availability	false
ee_Regulatory_Impact	<any>
ee_Political_Impact	true

Ok

Figure 3: Querying for a similar historic sustainable building refurbishment case

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When decision-makers want to retrieval a historic case to facilitate them making a sustainable building refurbishment decision, they should fill in the details related to the features of the building in question as well as the owner / occupant requirement through the user interface (Figure 3). In case users are unsure of the value for any parameter, they can simply leave it blank as this should not significantly affect the result of retrieval.

A nearest neighbour approach is used for case comparison whereby the degree of similarity of each parameter between the present case and each of the historic case is evaluated. The overall similarity scores of the historic cases can then be calculated. Those cases with the highest overall similarity scores will be reported (Figure 4). Decision-makers can examine the basic information of the retrieved cases. Should they convince the retrieved case is generally comparable to the present case, they can bring up the case details for further scrutiny.

2 Retrieved cases

Select	Time_cert...	Cost_cert...	Speed	Flexibility	Responsi...	Complexity	Price_co...	Risk_allo...	Quality	Procurem...	Tendering...	Contract_t...	Client_rati...
hku_...	false	false	High	High	Low	High	High	Low	Good	Competiti...	Selective ...	C21	Good
hku_...	false	true	Low	Medium	Low	High	Medium	High	Basic	Design a...	Selective ...	C22	Better

Add to Basket | Quit

Figure 4: Historic cases with high similarity scores are retrieved

While the retrieved sustainable refurbishment solutions might work well in the historic case, they may not result in the best outcomes in the present building in question. As a result, it is necessary to analyse the likely outcomes of those sustainable building refurbishment solutions under the current situation. Using the prototype model, the data inputted by the users and retrieved from the historic case will be fed into the energy model for energy performance analysis (Figure 5). This should help delineate which sustainable building refurbishment options would result in the greatest energy saving and emission reduction.

Manager HecResult

Level of Refrubishment	Refurbishment methods	Energy saving (kWh)	Percentage of Energy Saving	CO2 Emission Reduction (kg)	Percentage of Emission Reduction
1	Simple coating	114.25	0.012924208144796381	47.879999999999995	0.008043868314416466
1	Reducing storage temperature of electronic water heater	-1291.5	-0.1460972850678733	-1084.86	-0.18225712154506782
1	Reconfiguring air conditioner's temperature	374.0	0.04230769230769231	314.15999999999997	0.05277906578231155
1	Using induction cooker	263.15999999999997	0.0	221.05439999999996	0.03713726992319012
2	T5 flourescent	12.2202	0.0	10.264968	0.001724520694312844
2	LED lighting	5.537734375	0.0	4.651696875	7.814878258371469E-4
2	Compact flourescent lighting	5.249363636363635	0.0	4.409465454545454	7.407928039543062E-4
2	Electronic ballast	14.454	0.0	12.14136	0.0020397556599399233
2	Installing low-flow aerated showerhead	0.0	0.0	0.0	0.0
3	Stopping the draught	159.12	0.018	133.6608	0.022455093441928916
3	Tinted glazing	-16.824771007566703	-0.0019032546388650117	17.22	0.002892970183255045
3	Reflective glazing	12.3752289924333	0.0013999127819494684	41.748	0.007013688688184182
3	Double / multiple glazing	-2.3847710075667052	-2.697704759690843E-4	29.349599999999995	0.004930750156240549
1	Level 1 sum	-540.09	-0.06109615384615385	0.0	0.0
2	Using LED	-507.8780656250001	-0.06109615384615385	27.058024875	0.004545764180089914
3	LED & Reflective glazing	-336.3828366325668	-0.04169624106420439	202.466824875	0.03401454631020301

return

Figure 5: Energy performance analysis of a refurbishment case

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Conclusions

A prototype case-based reasoning model for sustainable building refurbishment has been developed. By referring to similar historic cases, owners / occupants can visualise the potential energy saving and emission reduction of different sustainable refurbishment solutions. This should increase the chance of success of sustainable building refurbishment schemes especially when the properties are of multi-storey multi-occupants nature. The next stage of development will focus on the other aspects such as the life cycle cost and disruption, and the findings of the subsequent stages will be reported when they become available.

Acknowledgement

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References

Aamodt, A. and Plaza, E. (1994). Case based reasoning: foundational issues, methodological variations and system approaches. *Artificial Intelligence Communication*, 7: 39-59.

Augenbroe, G. and Park, C. S. (2002). *Towards a Maintenance Performance Toolkit for GSA*. Draft Report for distribution in GSA, August 27. USA. Georgia institute of Technology.

Egbu, C. O. 1997. Refurbishment management: challenges and opportunities. *Building Research and Information*, 25(6): 338-347.

EMSD. (2010). *Hong Kong Energy End-use Data 2010*. Hong Kong. Environmental Protection Department, Government of HKSAR.

EPD (2010). *Guidelines to Account for and Report on Greenhouse Gas Emissions and Removals for Buildings (Commercial, Residential or Institutional Purposes) in Hong Kong, 2010 Edition*. Hong Kong. Environmental Protection Department, Government of HKSAR.

Imboden, D. (2000). Energy forecasting and atmospheric CO_2 perspectives: two worlds ignore each other. *Integrated Assessment*, 1: 321-330.

Levine, M., Ürge-Vorsatz, D., Blok, K., Geng, L. Harvey, D., Lang, S., Levermore, G., Mongameli Mehlwana, A., Mirasgedis, S., Novikova, A., Rilling, J. and Yoshino, H. (2007). Residential and commercial buildings, In *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK. Cambridge University Press.

Riesbeck, C. K. and Schank, R. C. (1989). *Inside Case-Based Reasoning*. Hillsdale, New Jersey: Lawrence Erlbaum Associates Publishers.

Taylor, S., Peacock, A., Banfill, P. and Li, S. (2010). Reduction of greenhouse gas emissions from UK hotels in 2030. *Building and Environment*, 45(6): 1389-1400.

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Session 17:

What should the limits to comfort and how can we manage them?

Chairperson:

Sánchez Ostiz, Ana

Dra. Arquitecta, Profesora Titular de Construcciones Arquitectónicas de la Universidad de Navarra, Directora del Master de Diseño y Gestión Ambiental de Edificios. EA UNAV

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The use of intelligent buildings to achieve sustainability through an architectural proposal for public buildings in Cairo

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Key words: ***intelligent buildings, sustainable buildings, sustainability, low energy consumption buildings.***

Abstract:

Through the study of the current situation in the city of Cairo, noted the existence of shortcomings in the design of public buildings to achieve the principles of sustainability.

By studying the reasons for this deficiency it founded that was because of the lack of a clear methodology for the sustainable building design in that city.

The research determined the most important elements must be achieved in public buildings in Cairo city to achieve the sustainability.

The research identified the most important elements of intelligent architecture that can be applied for public buildings in Cairo city to achieve the principles of sustainability in that city.

The research concluded an architectural proposal for public buildings in order to achieve sustainability elements using the recent techniques of intelligent buildings that are compatible with users in Cairo city in Egypt.

Aim of the research:

The research aims to provide a proposal for achieving sustainability by using the capabilities of intelligent buildings for the public buildings in Cairo city.

Research problem:

By studying the current situation of public buildings in Cairo, it appears clearly the lack of awareness of energy consumption of buildings and lack of achieving sustainability in most public buildings, because of the absence of an architectural proposal to achieve sustainability for public buildings in Cairo.

The scope and limits of the research:

The research determines a proposal to achieve sustainability for public buildings in Cairo city by using intelligent buildings capabilities.

1- Sustainability and public buildings in Cairo:

The need to apply sustainability and energy efficiency of public buildings in Egypt, especially in Cairo, has become urgent, due to the large of energy consumption of buildings in Cairo, Kurt Wiesegart [(1)] said that "Egypt can provide about a third of its electricity through improved energy efficiency in the buildings sector”. [(i)]

2- Intelligent Buildings:

Intelligent buildings have the advantage of automated systems that control the environment and communicate with users. With the increasing levels of sophistication in technology, intelligent systems can be used to achieve the requirements of sustainability.[(ii)]

[(1)] Dr. Kurt Wiesegart is the team leader of (MED - ENEC) project, which means raising the energy efficiency in the Mediterranean region .

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2-1 Sensors in intelligent buildings:

Sensors can monitor everything motion, temperature, humidity, precipitation, occupancy and light (iii).The buildings coexist with nature. Intelligent buildings can also reduce energy consumption and CO2 emissions.

2-2 Energy efficiency strategies in intelligent buildings:

Building automation systems (BAS) in intelligent buildings do wide facilities, they combine with building energy management systems (BEMS) and many systems and technologies to achieve the energy efficiency of buildings as the followings: (iv)

2-2-1 Using energy only when really required.

2-2-2 Use only the amount of energy that is actually required.(v)

2-2-3 Intelligent systems control heat loss in winter and heat gain in summer.

2-2-4 Intelligent systems shut down sources of energy consumption in spaces, such as lighting systems, air conditioning and other systems, in case of empty spaces, except emergency corridors and exits escape.

2-2-5 Intelligent systems can response to the environmental changes outdoor and indoor in order to decreasing the energy consumption.(vi)

2-2-6 Intelligent Systems can use natural light and outdoor air movement and changes of external temperatures to reduce the use of electrical and mechanical systems to reduce energy consumption.

2-2-7 Intelligent systems can save a part of the energy needed for the building through generating energy from renewable energy systems and integrating it into the total energy required for the building.(vii)

2-2-8 Efficient daylight penetration using suitable shading devices.

2-2-9 Efficient appliances that reduce the electricity consumption and cost.

2-2-10 Passive heating and cooling through the building envelope.(viii)

2-2-11 Building Energy Management and Control. (ix)

3-Advanced natural lightings techniques:

There're some methods used to transfer natural lightings to inner spaces like sun tunnel , smart light which is a technology that uses sunlight, electrofluidic cells, and a series of open-air ducts to use sunlight to naturally illuminate spaces deep inside (x), and blind system with shutter control unit (xi) which is an optimum incidence of external light with minimum glare results from the sun position.

Figure (1) shows sun tunnel (xii)

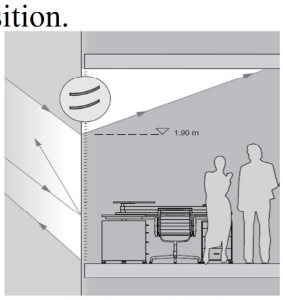

Figure (2) shows blind systems

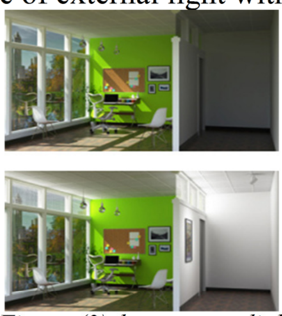

Figure (3)shows smart light

4-Geothermal heating and cooling systems:

Using of geothermal heating and cooling systems to reduce the energy consumption. (xiii)

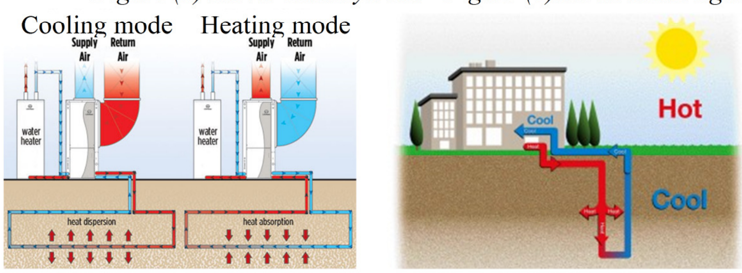

Figure (4) shows geothermal systems

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5- The current situation of public buildings in Cairo and its relation with sustainability:

By studying the current situation of public buildings in Cairo there's an indication of the absence of some of sustainability aspects, as follows:

	sustainable elements	The headquarters of the Bank for Development and Agricultural Credit (xiv) 	Children's Cancer Hospital 57357 (xv) 
Systems	Presence of Intelligent systems	Doesn't exist	exist
Water	Water management reduction & recycling	Doesn't exist	Using waste and water management systems
Outer environment	Minimizing negative impact on the surrounding environment	Don't do that	exist
Energy	Integration of intelligent systems to reduce energy consumption	Doesn't exist	exist
	Building Energy Management System (BEMS)	Doesn't exist	exist
	Efficient use of energy	Doesn't exist	exist
	Installing geothermal heating & cooling systems	Doesn't exist	Doesn't exist
	Double skin facades	double glazing	Doesn't exist
	Automated louvers	Doesn't exist	Doesn't exist
	Facades sensors to response to outer environment	Doesn't exist	Doesn't exist
	Controlling natural & artificial lighting	Doesn't exist	natural day lighting by using glazing facades
	Automatic daylight control	Doesn't exist	Doesn't exist
	Integration of lighting control systems through (BMS)	Doesn't exist	Doesn't exist
	Energy-saving lamps and Led lighting	Using compact fluorescent lamps	Using compact fluorescent lamps
	Installing energy-efficient ventilation systems	Doesn't exist	Doesn't exist
	Innovated design to reduce energy	Doesn't exist	Doesn't exist
	Encouragement natural ventilation systems	Doesn't exist	Doesn't exist
	Responsiveness to the environmental changes	Doesn't exist	Doesn't exist
Renewable energy	Installing renewable energy tools like photovoltaic panels (BIPV), wind turbines, and solar heaters.	Doesn't exist	Doesn't exist
Materials	smart materials	Doesn't exist	Doesn't exist
	The use of environment -friendly material	Doesn't exist	Few exist in facades and flooring
Recycling	Recycling materials	Doesn't exist	Sandstone
Indoor quality	Indoor air quality systems	HVAC systems	HVAC systems & Air purification system
	Indoor thermal quality systems	exist	exist
	Indoor acoustic quality systems	Doesn't exist	Few exist
pollution	Reduction pollution&Co2 emission	Doesn't exist	Few exist
Architectural treatments	Compatibility with climate &usage of treatments to deal with climate	Few exist	Medium exist

Table (1) shows the current situation of public buildings in Cairo and its relation with sustainability.

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5-1 The best practice examples in Egypt :

HSBC Bank Egypt Global Service Centre **,** is one of the best practice examples in Egypt, it has the first golden LEED certificate project in Egypt. [xvi]

HSBC Bank Egypt Global Service Centre:	 *Figure (5) shows HSBC Bank Egypt Global Service Centre.*
Location	Giza, Egypt's Smart Village.
Gross square feet	210,000 sq ft.
Space Type Use	Offices (17% of activities) .
Description of the building	- A four storey building Ground floor and three typical floors (3000 sq ms each) and two underground parking floors (4500 sq ms each). - The 3000 sq.m semicircular plan responds to an important corner plot in Smart Village with a sweeping fully glazed north facade and a mostly solid south service and gateway facade. An offset Atrium brings daylight from clerestory windows to the deep zones and break out areas.
Gold rating is the result of a range of green features including	-Energy consumption cost saving by 9%. -Chilled water consumption cost saving by 39%. -Domestic water consumption cost saving by 47%. -84% of construction waste diverted from landfill. [xvii]
Water efficiency	- 50% reduction in potable landscape water use**.** - 20% reduction in baseline indoor water use.
Energy and Atmosphere	- 28% improvement on baseline building performance rating**.** - The building uses smart technologies to help monitor and control energy use throughout the building. Meters will record electrical use and a centralized control system will determine usage trends and help building managers increase the efficiency of the building systems.
Indoor environmental quality	90% of occupied space has quality views.
Dust control	The building used an erosion and sedimentation control plan to improve dust control. Airborne dust was kept to a minimum by keeping sand piles covered and moistened with non-potable water.

Table (2) shows the best practice example in Egypt for sustainability.

6-Proposal to achieve sustainability in Cairo through using intelligent buildings:

6-1 Building management systems (BMS):

Presence of intelligent systems which integrate together to achieve sustainability (integrated management systems) like:

Building Energy Management System (BEMS), intelligent (HVAC) systems, fire alarm & fire fighting smart systems and electrical network management systems which include electrical power management system (EPMS) and intelligent lighting systems.[xviii]

6-2 Act on users:

Educating users on intelligent buildings, efficient use of energy, buildings sustainability, methods of energy conservation and conservation of natural resources.

6-3 Legislation and laws:

-Enactment the appropriate legislations to increase reliance on intelligent buildings for achieving sustainability, and implementing energy efficiency of buildings.

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-Not to allow to construct of any building doesn't achieve the sustainability requirements .

6-4 Water management:

The Intelligent systems reduce water consumption as the following:

- Adopting the process of recycling the collecting rainwater and wastewater after specific treatment and reuse in WC's and urinal flushing.
-The use of smart water sensors to minimize the loss in water when not needed.
- The use of smart sensors to lock water valves when any leakage happened this leads to minimize the waste of water.(xix)

6-5 Energy & atmosphere:

Installing Building Energy Management Systems (BEMS) that integrate with the building through the following:

6-5-1 Efficient use of energy in intelligent buildings:

Building Energy management systems (BEMS) operate on the efficient use of energy consumption by adapting elements of intelligent building through :

- Increasing reliance on natural light and reduce the reliance on artificial lighting.
- Increasing reliance on natural ventilation and architectural treatments to reduce reliance on mechanical systems in air conditioning systems and ventilation.
- Providing an appropriate thermal, lighting and acoustic environment depend on maximum utilization of natural resources and reduce energy consumption.
- Take advantage of renewable energy to provide a part of the energy required.
- Protection from solar radiation when it is not needed and encourages the entry of solar radiation if necessary.

6-5-2 Outer envelope:

-Installing intelligent Systems in facades to deal with ventilation, shading and brightness of the sun controlling natural light, temperature and humidity to achieve the best possible climate control, which reduces reliance on mechanical systems (HVAC) to reduce energy consumption.

-The use of moving louvers which are controlled automatically by automated system depending on the movement of the sun to protect against solar radiation in summer and encourage of solar radiation in winter, these louvers are covered by photovoltaic cells to generate electrical energy.

-The presence of the required sensors for facades like rain ,temperature ,relative humidity, wind direction, air quality, angles of the sun radiations and wind speed.

- Ensuring that the intelligent systems that deal with facades to increase reliance on natural lighting and natural ventilation to reduce energy consumption.

-The use of intelligent skins, double skin façades and intelligent facades systems to reduce energy consumption.(xx)

6-5-3 Lighting:

6-5-3-1 Integration of Lighting control systems:

-Lighting control systems integrate natural lighting with artificial lighting to maximize the use of natural lighting in order to minimize the use of artificial lighting, artificial lighting used only when the inability of natural lighting to provide illumination required rate, that controlled by building management systems (BMS) in intelligent buildings.(xxi)

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-Building Automation System (BAS) and intelligent integrated lighting systems can minimize the energy by using occupancy sensors for lighting that by:

-Controlling lighting where people work a predictable schedule.

- Automatically turn on and off lights by photocell or computer schedule.
- Modifying lighting levels through the use of photo chromatic windows.
- Managing energy consumption by monitoring room occupancy and adjusting lighting to suit.

6-5-3-2 Maximum natural lighting:

-Maximum use of natural lighting.

-The use of glass overlying of materials to allow light to pass preventing solar heat or glare, such as Laser cut panels, Prismatic panels and light diffusing systems.

- Delivering natural light to deep areas, such as basements by Light pipe systems and mirror ducts.

-Installing sun tunnel techniques to provide natural lighting.

- Installing smart light systems to lighten the deep spaces.(xxii)

-Installing roof skylights and roof windows over atriums, inner spaces and corridors to provide natural lighting to save energy, these skylights can be supported by intelligent mechanical system that can prevent solar radiation in summer periods.(xxiii)

6-5-3-3 Artificial lighting:

-Installing energy-efficient lightings like energy saving lamps and Led lighting.

6-5-4 HVAC systems in Intelligent Buildings:

6-5-4-1 Intelligent HVAC systems:

- Installing energy-efficient air-conditioning.

-Using intelligent Systems that integrate with (HVAC) Systems that lead to energy control.

- The system consists of : sensors to measure temperature, flow rate of air inside the rooms and electronic control devices to adjust the air flow rate as needed automatically. Climate sensors can measure humidity, switch off air conditioning machines when room is empty to save energy.

-HVAC intelligent systems are integrated to provide natural ventilation.

-Installing Geothermal Heating and Cooling systems.

6-5-4-2 Natural Ventilation:

- Installing energy-efficient ventilation systems in building they use less energy.

-Encourage natural ventilation, which include ventilation holes in the walls and wind towers thus to minimize air conditioning use.

6-5-4-3 Responsiveness to the environmental changes:

-Sensors can monitor everything in building like motion, temperature, humidity, precipitation, occupancy and lights. Intelligent Systems can respond to the environmental changes indoor and outdoor.

-System used to control (HVAC) and lighting systems makes building responsive for thermal and climatic changes.

6-5-5-Heating systems:

-Installing energy-efficient boilers.

-Installing systems generate biomass fuel for boilers and heating.

- Use of solar energy to heat water controlled by smart systems.(xxiv)

6-5-6 Renewable energy:

5-5-6-1 Take advantage of renewable energy as following:

-The integration of photovoltaic cells with the building, building integrated photovoltaic cells (BIPV) to provide some of electricity needed to building.

-Generating Electricity by wind turbines on roofs or external facades that can provide part of the electrical energy required.

- Installing techniques for electric power generation, such as Parabolic dish collectors.

5-5-6-2 Installing solar water heating systems use heat from the sun to work alongside the conventional water heater.

5 -5-6-3 Installing of the geothermal heating and cooling systems that integrate with the building through intelligent systems.

6-6 Integrated systems:

The systems integrate together in intelligent buildings to achieve the best benefits and less consumption of energy. [xxv]

6-7 Smart materials:

- The use of smart materials on facades, in order to reduce energy consumption.
-The use of color-changing smart materials in windows to prevent glare and undesirable reflection, these materials change its colors when exposed to electrical current.
-The use of (HOE) material which allows natural light to pass and prevents solar radiation.[xxvi]
-The use of smart self cleaning glass on exterior facades where there are a large percentage of air dust in Cairo.
-Installing of electro-changing smart materials which can convert energy from a case to another, like thermo-electrical materials that can convert thermal energy to electrical energy, and Piezoelectrical materials which can generate electrical energy by pressing that can be used in corridors and outdoor roads.[xxvii]

6-8 Materials & Resources:

- The use of environment-friendly material non-polluting and biodegradable.
-The use of recyclable materials .
-Selecting materials in building that can be reused later in new construction.

6-9 Indoor Environment Quality:

-The usage of intelligent systems to achieve the optimization for comfort and health for indoor environment.
-Achieving indoor visual quality.
-Using intelligent systems that integrate with artificial and natural lighting systems to achieve the required lighting for indoor spaces.
-Using intelligent systems that integrate with (HVAC) systems to achieve indoor air quality and thermal quality.
-The use of smart materials and insulating materials for facades with integration by intelligent systems to achieve indoor acoustic quality.

6-10 Innovation designs:

- Innovative architectural designs for designing forms, areas of openings, building orientation, windows orientation, protection from solar radiation in summer, increasing heat gain in winter, reducing water consumption and utilization of renewable energy, for compatibility with the environment, and reducing the energy consumption.
-Providing innovative solutions to control the permeability of natural lighting to the areas that are away from windows.[xxviii]

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-Providing innovative solutions to control the movement of air in inner spaces.

6-11 Pollution reduction:

-Control the gases, pollutants and carbon dioxide by (HVAC) systems, which work to prevent the entry of these gases to the building and reduce the production of polluting gases.

-Installing stoves that use the power generated from renewable energy sources.

-Increasing landscape areas indoor and on roofs to increase the amount of oxygen and reduce carbon dioxide.

- Integration of Biomass which is a low carbon renewable fuel.

6-12 Avoiding negative impact on the environment and site:

Buildings must avoid any negative impact on the sites and the surrounding environment.

6-13 Compatibility with climate :

-Protecting the facades and windows from solar radiation in summer.

-The use of large thermal resistance materials on external facades and increasing shaded areas on facades as much as possible.

-Reducing the areas of windows on the exterior facades which exposed to large amount of solar radiation.

-The use of sun-breakers on the exterior windows to protect from solar radiation.

-The use of vacuum double glazing that provided with film to protect from heat transfer.

-Adding thermal insulation for walls and roofs.[xxix]

-North direction is the preferred orientation.

-Adjust long side of the building to north direction.

-Increasing natural ventilation, adding internal courtyards to the building.

-Adding sky lights areas to increase the amount of natural light which must be designed to prevent the entry of solar radiation in summer.

-Increasing the underground spaces in designs to protect from solar radiation and high air temperature. [xxx]

7- Threats and obstacles to apply the proposal:

- Lack of awareness for decision-makers of the importance of sustainability for public buildings in Cairo.
- The lack of specialists who are familiar with the advantages of intelligent buildings and sustainability of buildings.
- The lack of availability of intelligent buildings technologies locally.
- The absence of legislation needed to implement the sustainability of public buildings in Cairo.
- Lack of funding required to modify existing public buildings so as to comply with the requirements of sustainability by using the intelligent buildings technologies.
- Most of Egyptian codes & standards do not take into consideration the sustainability factors.
- The initial cost of using renewable energy , implementing of sustainability and installing of intelligent buildings systems is considered fairly high.

Conclusion:

1 - Most of existing public buildings in Cairo don’t take into account the aspects of sustainability and the fundamentals of energy conservation.

2- There's no use of the capabilities of intelligent buildings in the field of sustainability of public buildings in Cairo.

3- Intelligent building systems can be employed to achieve sustainability.
4- The increasing of global trends in the fields of energy conservation and renewable energy that can be used to reduce energy consumption for public buildings.
5- The absence of a comprehensive proposal for achieving sustainability and energy efficiency of public buildings in Cairo.
6-The research submit a proposal for achieving sustainability for public buildings in Cairo through the capabilities of intelligent buildings.

Recommendations:

1-Applying the proposal to all new buildings that will be built in Cairo.
2-Making the obligation for the owners to provide a confirmation prove that the building achieve the terms of sustainability and to be a condition for the approval of the permits.
3- Activating the role of research centers and universities in the field of intelligent buildings to achieve sustainability in Cairo.
4- Assessing existing projects in Cairo and making the required modifications to achieve the aspects of sustainability for these buildings.
5- Increasing the users' awareness of intelligent buildings and sustainability.
6- Increasing the educational interest in the fields of sustainability and intelligent buildings.

References:

(1) http://www.akhbarak.net/articles/14759210 ,Access date 15/5/2014.
(1) Tang, T. (2012) Sustainable buildings: smart, green and people-friendly. The College of Estate Management CEM . Occasional Paper Series United Kingdom .
(1) http://www.futureagenda.org/pg/cx/view#415 ,Access date 12/4/2014.
(1) Nikolaou,T. et al (2004)Introduction to Intelligent Buildings, Intelligent Buildings Handbook. chapter 1. Athens.
(1) http://www.abb.com/knx , Access date 18/4/2014.
(1) Schittich, C.(2003) Solar Architecture ,Strategies .Visions .Concepts .BirKhauser .Basel.
(1) Hendrson,H. (2012) Becoming a Green Building Professional. John Wiley& Sons, Inc. USA.
(1) Hight, C. & Perry, C.(2006) Collective Intelligence in Design. John Wiley & Sons. London.
(1) Nikolaou,T. et al (2004) P. ref.
(1) http://cleantechnica.com/2013/11/12/smartlight-set-change-way-use-energy/ ,Access date 20/4/2014.
(1) http://www.bicsi.org/uploadedfiles/pdfs/presentations/region_events/Northeast_LaurelMD_03-14-13/BuildingIntelligentBuildings.pdf ,Access date 28/4/2014.
(1) http://howtobuildit.org/2013/10/02/ho-to-install-a-bathroom-sun-tunnel/,Access date 12/4/2014.
(1) http://blog.heatspring.com/how-can-i-design-geothermal-systems-a-4-step-guide-to-designing-geothermal/
(1) http://www.arabcont.com/projects/ ,Access date 28/4/2014.
(1) http://www.healthcaredesignmagazine.com/article/childrens-healthcare-21st-century-egypt
(1) http://www.evolveea.com/work/hsbc-cairo,Access date 18/7/2014.
(1) http://www.zawya.com/story/ZAWYA20100602111206/ ,Access date 18/7/2014.
(1) Wang, S.(2010) Intelligent Buildings and Building Automation. Spon Press. London.
(1) Osso,A. et al (1996) Sustainable Building Technical Manual. Public Technology Inc.USA.
(1) Poirazis, H. (2004) Double Skin Facades for Office Buildings. Department of Construction and Architecture, Division of Energy and Building Design. Lund University, Lund Institute of Technology, Lund.
(1) Karatasous,S. & Santamouris,M. (2004) Application of Intelligent Building evaluation matrix tool in case studies. Intelligent Buildings Handbook. chapter 5 .Athens.
(1) Phillips, D. (2004) Daylighting ,Natural Light in Architecture. Architectural Press. Oxford.
(1) Stano, A. & Hawthorne, C. (2005) The Green House, New Direction in Sustainable Architecture. Princeton Architectural Press. New York.
(1) Williamson, T. et al (2003) Understanding Sustainable Architecture .Spon Press. New York.
(1) Croome , D. (2004) Intelligent Buildings Design, Management and Operation .ASCE Press . Alexander Bell Drive . Reston . USA .

ISBN: 978-84-697-1815-5

[1] Ritter, A. (2007) Smart Materials in Architecture. Interior Architecture and Design. BirKhauser Publisher. Berlin.
[1] Addington, M. & Schodek, D.(2005) Smart Materials and New Technologies .Architectural Press .Elsevier. New York.
[1] Williams, D.(2007)Sustainable Design ,Ecology ,Architecture ,and Planning. John Wiley & Sons, Inc. New Jersey.
[1] Fouda, A. (2005) Energy code and its relationship to the building's outer envelope between theory and practice with special mention to the Egyptian Energy Code. Master Thesis. Faculty of Engineering. Cairo University. Egypt .
[1] Al-Abbasi, Sh. ,(2011)Energy Conservation in Residential Buildings Using Green Architecture Principals. Master thesis. Cairo University. Cairo, Egypt.

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Energy and environmental impacts of home automation components

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Abstract: *Life Cycle Assessment is applied to estimate the life cycle energy and environmental impacts of five components used in the home automation systems: an electricity meter, an actuator with an integrated current sensor, a web server audio/video, an interface with infrared emitter, a multimedia touch screen.*

For each component, the impacts related to "one unit of product" (selected as functional unit) are assessed following a "from cradle to grave" approach, including the manufacturing, operation and end-of-life steps.

The results showed that the operation step gives a contribution higher than 54% on primary energy consumption and variable from about 54% to about 99% on environmental impacts, with the exception of the operation of multimedia touch screen, which causes from 11% to 60% of the environmental impacts. For this component, relevant impacts are caused by the manufacturing step.

The end-of-life-step has an effect on energy and environmental impacts lower than 6.5%.

Keywords: Life Cycle Assessment, home automation, energy, environmental impacts

Introduction

The home appliances and air conditioning systems make buildings one of the most critical areas for the impact of energy consumption on natural environment. Thus, the management of energy consumption is of paramount importance to reduce the energy and environmental impacts of buildings.

Home automation systems can be used to improve energy efficiency and increase energy saving in buildings. In these systems automated controls can turn equipment on or off, or adjust operating settings at predetermined times; they can be triggered on site or remotely; they can adjust equipment operation in response to changes in the home environment (e.g. temperature) (1).

Automated systems use energy during their life-cycle, so they produce energy savings only if they save more energy than they use along their life-cycle.

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To assess correctly the real benefits due to the installation of home automation technologies, their life cycle energy and environmental impacts should be estimated.

A useful tool to estimate resource use (raw materials and energy), energy and environmental burdens related to the full life cycle of products and services is the Life Cycle Assessment (LCA) methodology (2).

The LCA consists of four steps, briefly described in the following (3, 4):

- Goal and scope definition, that includes a description of the intended use of the study and of the product system in terms of system boundaries (unit processes that are part of a product system), functional unit (quantified performance of a product system for use as a reference unit), allocation procedures, impact categories selected and methodology of impact assessment, etc.;
- Life Cycle Inventory (LCI) analysis, that involves data collection and calculation procedures to quantify the resources consumption, the air, water and soil emissions, and the waste production;
- Life Cycle Impact Assessment (LCIA), that is aimed at evaluating the significance of potential environmental impacts using the LCI result;
- Life cycle interpretation, which is the final step of the LCA procedure, in which the results of a LCI and/or a LCIA are summarized and discussed as a basis for conclusions, recommendations and decision-making in accordance with the goal and scope definition.

In this paper, the life cycle energy and environmental impacts of five components used in the home automation systems are assessed, by applying the LCA methodology, in compliance with the international standards of series ISO 14040 (3, 4). The analysis represents one of the first studies aimed at assessing the energy and environmental impacts of home automation components.

The study is developed within an Italian project on automation and rationalization of residential energy consumption, funded by the Italian Ministry of economic development (5, 6).

Goal and scope definition
Following a life cycle approach, the main goals of the study are:

- To assess the energy and environmental impacts of five components used in the home automation systems: an electricity meter, an actuator with an integrated current sensor, a web server audio/video, an interface with infrared emitter, a multimedia touch screen;
- To identify, for each component, the life cycle steps that are characterized by higher impacts.

The results of the analysis are referred to a functional unit (FU), which is defined as the reference unit through which the performance of a product system is quantified in a LCA (3). In the case study, each examined component is selected as FU, as following:

- FU_1: one electricity meter, that is employed to measure electric currents and voltages of different lines;

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- FU_2: one actuator with an integrated current sensor, that measures the energy loads and, if necessary, disconnect the appliances following an established priority;
- FU_3: one web server audio/video, that controls local and remote applications of the home automation system through a webpage;
- FU_4: one interface with infrared emitter. It controls the air conditioners operation by infrared commands;
- FU_5: one multimedia LCD touch screen, which is used for the management of the home automation system.

The system boundaries were selected following a “from cradle to grave” approach. They include the following life cycle steps:

- Manufacturing step, that includes the supply of raw materials and energy sources, the manufacturing of each product and the end-of-life of waste produced in this step;
- Operation step, that is analysed considering the transport of the products to the final users (medium distance: 780 km), and the life cycle of electricity consumed during the useful life of the examined FUs, that is assumed to be 20 years (365 days/year);
- End-of-life step, that includes the transport of waste to the disposal plants (medium distance: 100 km) and the end-of-life treatment processes (recycling process for plastic, paper and cardboard; specific treatments for waste electrical and electronic equipment for dismantling the other parts of the examined products).

The installation and maintenance steps are not taken into account as their energy and environmental impacts can be assumed as negligible.

The energy and environmental indices selected to summarize the inventory data and to assess the life cycle impacts of the investigated products are: global energy requirement (GER), non-renewable energy requirement (NRE), renewable energy requirement (RE), global warming potential (GWP), ozone depletion potential (ODP), human toxicity - cancer effects (HTc), human toxicity - non-cancer effects (HTn-c), particulate matter (PM), ionizing radiation - effect on human health (IRh), ionizing radiation - effect on ecosystem (IRe), photochemical ozone formation (POF), acidification (Ac), terrestrial eutrophication (TE), freshwater eutrophication (FE), marine eutrophication (ME), freshwater ecotoxicity (FET), land use (LU), water resource depletion (WRD), mineral - fossil - renewable resources depletion (RD).

Cumulative Energy Demand method is used to account for the total, renewable and non-renewable primary energy requirement of the assessed products (7, 8). The environmental impact assessment is carried out by means the ILCD 2011 Midpoint method, elaborated by Prè (8) according to the European Commission (9).

Life Cycle Inventory analysis

According to the framework provided by ISO 14040 (3) and ISO 14044 (4), the inventory analysis is carried out to quantify the inputs and outputs of the examined systems by means of a mass and energy balance.

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This step allows for the estimation of resource consumption, air, water and soil emissions, and waste production, during the life cycle of the FUs.

Table 1 shows the main components of the examined products and their daily energy consumption. The information was collected with the support of the productive firm.

The eco-profiles of materials and energy sources, and the impacts related to the transport and end-of-life steps are referred to the Ecoinvent database (10), with the only exception of the recycling processes that are taken from the Buwal 250 database (11).

	FU_1	FU_2	FU_3	FU_4	FU_5
Capacitors (g)	0.99	0.44	3.2	0.36	6.15
Casing and other components (g)	38.01	25.25	115.58	20.43	800.02
Connectors (g)	8.41	18.92	7.97	5.94	25.02
Diodes (g)	0.31	0.35	1.24	1.02	0,79
Fuses (g)	-	0.20	-	0.20	-
Inductors (g)	0.05	0.10	2.18	1.10	9.65
Integrated circuits (g)	1.78	1.50	5.39	1,61	10.61
Motor (g)	-	-	-	-	79.33
Packaging (g)	24.51	21.51	217.02	105.02	906.51
Printed circuit boards (g)	0.01	0.01	0.04	0.004	0.15
Relays (g)	-	16.59	16.59	-	-
Resistors (g)	0.19	0.18	0.45	0.80	0.61
Switches (g)	0.21	0.42	0.21	0.21	1.46
Transistors (g)	0.04	0.06	0.16	0.05	0.21
Touch screen (g)	-	-	-	-	436
Daily electricity consumption (kWh/day)	0.034	0.028	0.054	0.007	0.052

Table 1: Main components and daily energy consumption of the selected FUs

Life cycle impact assessment and interpretation

In the following, the assessment of the life cycle energy and environmental impacts of the examined FUs was carried out. The results relating to primary energy consumption are shown in Table 2.

A detailed analysis of the results shows that:

- FU_5 is characterized by the higher energy impact, while the lower impact is caused by FU_4;
- For all the examined components the share of renewable energy is lower than 8.2% of the total primary energy consumption;
- The operation step has a percentage incidence on the primary energy consumption variable from about 54% (FU_5) to about 98% (FU_1). The 99.9% of this contribution is caused by the eco-profile of electricity consumed during the life cycle of each product;
- The contribution of the manufacturing step ranging from 2% to 8% for all FUs, mainly caused by the manufacturing of integrated circuits and printed circuit boards. The only exception is represented by FU_5, for which this step is responsible of about 45.5% of the energy impact, mainly caused by the manufacturing of the LCD screen (about 84.5%);

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- The incidence of the end-of-life step on the energy consumption is negligible (lower than 0.5%).

The environmental impacts caused by the life cycle of the products are shown in Table 2.

Examining the contributions of each life cycle step on the total impacts, the following considerations can be made:

	Manufacturing	Operation	End-of-life	Total
FU_1				
NRE (MJ)	50.70	2449.44	0.44	2500.57
RE (MJ)	3.05	220.49	0.05	223.60
GER (MJ)	53.75	2669.93	0.49	2724.17
FU_2				
NRE (MJ)	47.07	2022.94	0.42	2070.44
RE (MJ)	2.80	182.10	0.05	184.95
GER (MJ)	49.87	2205.04	0.47	2255.39
FU_3				
NRE (MJ)	164.51	3923.68	4.35	4092.54
RE (MJ)	10.00	353.17	0.49	363.66
GER (MJ)	174.51	4276.85	4.84	4456.20
FU_4				
NRE (MJ)	48.11	536.20	2.95	587.25
RE (MJ)	2.81	48.24	0.27	51.32
GER (MJ)	50.92	584.44	3.22	638.57
FU_5				
NRE (MJ)	3222.96	3762.94	12.57	6998.47
RE (MJ)	206.51	338.44	1.88	546.83
GER (MJ)	3429.47	4101.38	14.45	7545.30

Table 2: Primary energy consumption of the selected FUs

Impact category	FU1	FU2	FU3	FU4	FU5
GWP (kg CO_{2eq});	162.57	134.56	265.63	38.06	473.03
ODP (kg CFC-11_{eq})	1.4E-05	1.2E-05	2.3E-05	3.4E-06	3.6E-05
HTc (CTU_h)	7.1E-06	5.9E-06	1.2E-05	2.0E-06	4.1E-05
HTn-c (CTU_h)	6.6E-06	5.5E-06	1.2E-05	2.3E-06	5.7E-05
PM (kg PM $2,5_{eq}$);	6.2E-02	5.1E-02	1.0E-01	1.5E-02	2.8E-01
IRh (kg $U235_{eq}$);	3.0E+01	2.5E+01	5.1E+01	7.5E+00	1.1E+02
IRe (CTU_e);	9.7E-05	8.1E-05	1.6E-04	2.4E-05	3.4E-04
POF (kg $NMVOC_{eq}$)	4.3E-01	3.5E-01	7.0E-01	1.0E-01	1.5E+00
Ac (mol $H+_{eq}$)	9.6E-01	7.9E-01	1.6E+00	2.3E-01	3.2E+00
TE (mol N_{eq})	1.5E+00	1.2E+00	2.4E+00	3.5E-01	5.7E+00
FE (kg Peq)	5.4E-02	4.5E-02	9.8E-02	1.8E-02	3.9E-01

ME (kg N_{eq})	1.4E-01	1.1E-01	2.3E-01	3.3E-02	1.1E+00
FET (CTU_e)	1.4E+02	1.2E+02	2.6E+02	4.7E+01	1.6E+03
LU (kg deficit C)	1.7E+02	1.4E+02	2.8E+02	4.0E+01	3.9E+02
WRD (m^3 $water_{eq}$)	1.0E-01	8.6E-02	1.8E-01	2.7E-02	6.8E-01
RD (kg Sb_{eq})	1.1E-03	8.0E-04	4.6E-03	1.2E-03	8.2E+00

Table 3: Environmental impacts of the selected FUs

- The higher environmental impacts are caused by FU_5, while FU_4 is responsible of the lower impacts;
- The operation step of FU_1, FU_2, FU_3 and FU_4 has an incidence on all the examined impacts (except for mineral - fossil - renewable resources depletion) ranging from about 54% to about 99%, mainly caused by the electricity consumption. The manufacturing step of the above FUs is responsible for about 77% to 96% of the impact on mineral - fossil - renewable resources depletion, and contributes for less than 45% on the other impacts.
- With regard to FU_5 the operation step gives a contribution on the environmental impacts variable from 11% (freshwater ecotoxicity) to 60% (land use), and has a null impact on mineral - fossil - renewable resources depletion. The incidence of manufacturing step ranging from about 32% (land use) to about 100% (mineral - fossil - renewable resources depletion), and is mainly caused by the manufacturing of the LCD screen;
- For all the examined products, the end of life step has an effect on the freshwater ecotoxicity lower than 6.5%, and is responsible for less than 1% of the other environmental impacts.

Conclusions

The study aimed at evaluating the energy and environment impacts of five components used in the home automation systems. The analysis was carried out through the application of the LCA methodology, in accordance with the standards of the ISO 14040 series.

The analysis highlighted that the main energy and environmental impacts related to the life cycle of the selected FUs are caused during the operation step and, in particular, are related to the eco-profile of electricity consumed during the life cycle of the products. The only exception is represented by the impact on mineral – fossil – renewable resources depletion, which is mainly caused by the manufacturing step of the products.

The results of the research can represent a “knowledge basis” to assess the real advantages arising from the installation of home automation technologies integrated with the traditional electric systems for improving energy efficiency and energy savings in buildings.

References

1) Ryan, P., Pavia, M. (2013). Home automation. Your Home – Australia’s guide to environmentally sustainable homes. Australian Government.

2) Beccali, M., Cellura, M., Longo, S., Nocke, B., Finocchiaro, P. (2012). LCA of a solar heating and cooling system equipped with a small water-ammonia absorption chiller. *Solar Energy*, 86 (5): 1491-1503, doi: 10.1016/j.solener.2012.02.010.

ISBN: 978-84-697-1815-5

3) ISO 14040 (2006). Environmental management – Life cycle assessment –Principles and framework.

4) ISO 14044 (2006). Environmental management – Life cycle assessment –Requirements and guidelines.

5) Ippolito, M.G., Riva Sanseverino, E., Zizzo, G. (2014). Impact of BACS and TBM Systems on the Energy Performance Class of a Residential Buildings: an Italian Case Study. *Energy and Buildings*, 69: 33-40.

6) Ippolito, M.G., Zizzo, G., Piccolo, A., Siano, P. (2014). Definition and application of innovative control logics for residential energy optimization. Speedam 2014, Ischia, Italy, 18-20 June 2014.

7) Frischknecht, R., Jungbluth, N., Althaus, H.J., Bauer, C., Doka, G., Dones, R., Hischier, R., Hellweg, S., Humbert, S., Köllner, T., Loerincik, Y., Margni, M., Nemecek, T. (2007). Implementation of Life Cycle Impact Assessment Methods. *Ecoinvent report No. 3, v2.0.* Swiss Centre for Life Cycle Inventories. Dübendorf.

8) PRè-Product Ecology Consultants (2012). SimaPro7, environmental database.

9) European Commission, DG Joint Research Centre - Institute for Environment and Sustainability (2012). Characterization Factors of the ILCD Recommended Life Cycle Impact Assessment Methods. Database and Supporting Information, first ed. Luxembourg Publications Office of the European Union. EUR 25167.

10) Frischknecht, R., Jungbluth, N., Althaus, H.J., Doka, G., Dones, R., Heck, T., Hellweg, S., Hischier, R., Nemecek, T., Rebitzer, G., Spielmann, M. (2007). Overview and Methodology. *Ecoinvent Report No. 1, ver.2.0.* Swiss Centre for Life Cycle Inventories. Dübendorf (CH).

11) Spriensma, R. (2004). SimaPro Database Manual e the Buwal 250 Library. Pré Consultants, the Netherlands. Available on: www.pre-sustainability.com.

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The comfort range as a nonlinear function and its role on evaluating the design performance of low energy buildings

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Abstract: *In the last decade, the adaptive comfort theory has become a fundamental tool for evaluating thermal performance in buildings, most notably in the naturally ventilated and low energy design sector. Still there are some evidences on how comfort limits proposed in the two prevailing adaptive comfort standards (ASHRAE 55-2010 & EN 15251) could become more responsive to the different climate types like hot arid, warm humid, temperate and cold, due to a differentiated calculation of the mean comfort line leading to nonlinear correlations between outdoor and indoor comfort temperature.*

The first problem addressed by this paper is to complement the comfort limit's definition by exploring the comfort range calculation. The current state of the art in adaptive theory assumes the comfort range as a constant offset symmetrical to the mean comfort line. We start exploring a World Wide Database of comfort votes (RP-884) and search for evidence for the constant offset, or alternative patterns. Thereafter we investigate the dependence between indoor comfort range and outdoor prevailing temperatures.

The second task is to integrate the former proposal (the mean comfort curve) and the current proposal (comfort range) and, moreover, to analyze their usability as an evaluation tool. For that a thermal simulation with prototypes in different climates is performed and the results are compared.

Key words: Comfort limits, Adaptive theory, Thermal Performance, Low energy design

Introduction

In 1997 the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) commissioned a number of field surveys, which originated the RP-884 database (De Dear et al 1998) and later led to the first standard in adaptive comfort: ASHRAE Standard 55-2004.

Since 2007 the ASHRAE 55-2004 has a European counterpart: the EN 15251. Considering the research design, the basic differences are the criteria how to classify buildings (type or operation modi) and the methods to calculate both the comfort temperature and the outdoor temperature. Both of the comfort models have been developed on the base of research in office buildings, however they are intended to be applied to all sedentary activities including dwelling.

Despite the different calculation methods both standards present a comfort zone divided into two seasons: the naturally ventilated (or "free-running") and the heated or cooled season. During the naturally ventilated season the comfort zone's pattern is inclined whilst the heated or cooled season presents a flat profile. Note in Figure 1 the similarity of the resulted formulae. (For more detailed description see Humphreys et al 2010, Nicol & Humphreys 2010, and De dear 2011).

Related Works

De Siqueira & Dietrich (2013) showed some advantages in assessing thermal comfort for the main comfort zones separately.

For that the RP-884 was parsed and the available climate classification was substituted by the more widespread Köppen-Geiger classification. Moreover only the major climate groups were used and the cold climates were put together resulting in:

A -Warm humid, B- Hot arid, C- Temperate, D- Cold (not considered due to the absence of naturally ventilated buildings in this category)

Each file in the raw data represents a large amount of parameters, and the most important were: user's comfort vote (in a 7-point scale ranging from -3 "too cold" to +3 "too hot"), indoors temperature (real time), outdoor temperature (day mean) and air speed.

To find the comfort temperature only the votes between -1 and +1 were considered and represented in combination with the indoor temperature in which they were applied. The represented indoor temperature is an adjusted operative temperature, which is the given operative temperature, after the influence of air speed upon comfort sensation has been reduced. This reduction is described in the following formula (EN 15251).

(1) $$\theta_{in} = \theta_i - \left(7 - \frac{50}{4 + 10 * V}\right)$$

For V>0,5 m/s, V=Air speed, θ_{in}*=adjusted indoor temperature,* θ_i*=measured operative temperature (raw database)*

The comfort temperature is commonly represented at the y-axis and the x-axis is used to represent the outdoor temperature. In this case, it is based upon the rounded mean outdoor temperature recorded on the raw file. The rounding helped to cluster the comfort votes in 1K intervals and to form a grid. Thereby it is possible to define, for each outdoor temperature value, the mean comfort vote.

Subsequently, as shown in Figure 1, the mean comfort curve is calculated as a polynomial regression upon the mean comfort votes.

The resulted algorithm for A where: θ_i= comfort temperature, θ_o=mean outdoor temperature.

(2) For $\theta_o<22°C$: $\theta_i = 22.7°C$; for $\theta_o>30°C$: $\theta_i = 30.3°C$; *else:*

$$\theta_i = -0.02390\theta_o^3 + 1.86680\theta_o^2 - 47.5290\theta_o + 421.34$$

For B:

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(3) For $\theta_o<8°C$: $\theta_i = 18.7°C$; for $\theta_o>35°C$: $\theta_i = 32.5°C$; *else:*

$\theta_i = -0.0014\theta_o^3 + 0.0911\theta_o^2 - 1.2127\theta_o + 23.316$

For C:

(4) For $\theta_o<10°C$: $\theta_i = 19.3°C$; for $\theta_o>29°C$: $\theta_i = 29.2°C$; *else:*

$\theta_i = -0.0024\theta_o^3 + 0.1393\,\theta_o^2 - 1.9593\,\theta_o + 27.392$

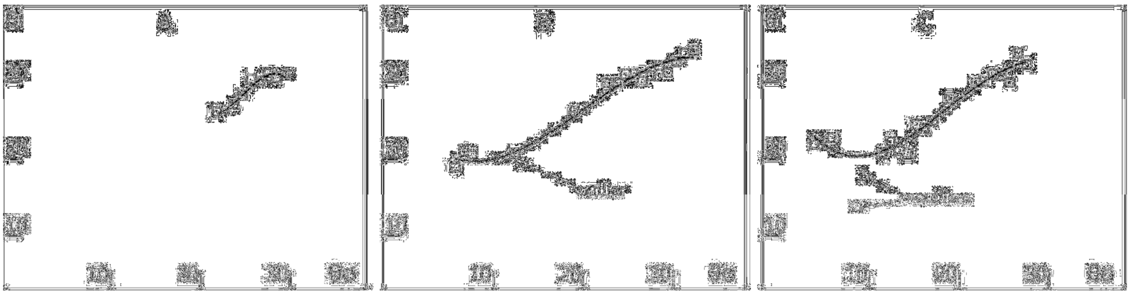

Fig. 1 – Mean Comfort Curve for three main climate groups: A- humid tropic, B- hot arid, C- temperate (θ_i= comfort temperature, θ_o=mean outdoor temperature)

Hypothesis

There are two questions to be investigated in this paper about the comfort range:

1. Is it necessarily symmetrical to the mean comfort line?

2. Is it a constant value along the mean comfort curve as assumed by the prevailing comfort standards?

Methods

For testing whether the comfort range is symmetrical to the mean comfort curve or not, we observed how the comfort vote (ASHRAE scale) reacts, while the distance between the indoor temperature and the mean comfort curve (all climate groups included) grows. We used the same method as for assessing the mean comfort curves, this time plotting the rounded comfort offset (the difference between the registered indoor temperature and the calculated mean comfort value) against the mean comfort vote. Figure 2 shows that the resulted curve is nearly symmetrical to the axis, which firstly confirms the first hypothesis and secondly that the mean comfort curve method works.

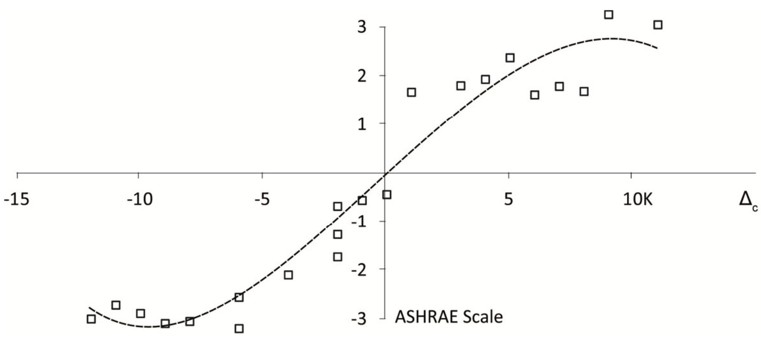

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Fig. 2 – ASHRAE comfort vote (y) plotted against the difference between the operative and the mean comfort curve (x)

Thereafter we investigated the dependence of the indoor comfort range on the outdoor climate considering that, following the adaptive comfort theory, people will adapt both their comfort expectation and behaviour in order to maintain the comfort state according to the outdoor stimuli (de Dear et al 1998). We assumed that the indoor comfort range might be proportional to the outdoor daily swings, so we plotted the mean indoor range (in the interval -1, +1 comfort votes) against the rounded outdoor daily swings.

The result was a polynomial curve with high degree of significance (r^2=0.87) which proves that, just as the mean comfort sensation, the range of the comfort zone also might be influenced by the climatic conditions experienced.

Figure 3 shows the comparison between the linear and the curve regression for the for the indoor comfort range (for both over and below the mean comfort curve). The resulted comfort range Algorithm is:

(5) For $\theta_{ods}<4K$: $\theta_{icr} = 1.1K$; for $\theta_{ods}>17K$: $\theta_{icr} = 2.4K$; *else:*

$\theta_{icr} = -0.0012x^3 + 0.0382x^2 - 0.2566x + 1.6098$

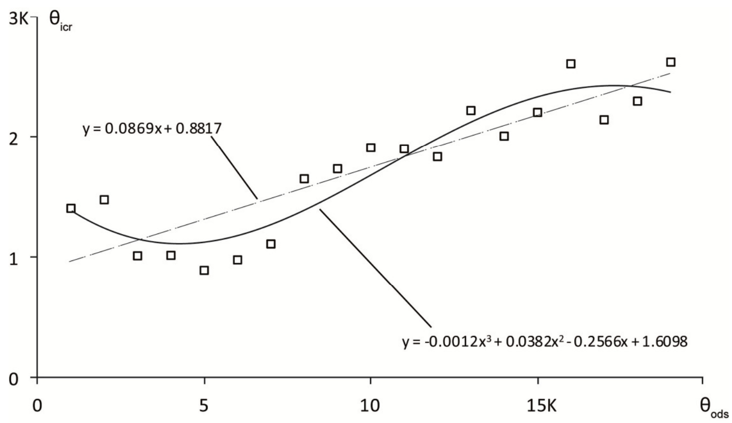

Fig. 3 – dependence of indoor comfort range (the offset above and below the mean comfort line) on the outdoor daily swing.

Another interesting issue considered by the two prevailing adaptive comfort standards is the influence of the historical climate conditions on comfort expectation. For analogy we assumed that the current comfort range definition must follow the same patterns

In order to consider the influence of the past days on the comfort range definition we proposed to apply the weighted mean coefficient from de Dear (2011) upon the daily swings, therefore we find what we call the "running mean outdoor swing" (θ_{rmos}).

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(6) $\theta_{rmos}= \theta_{dsw-1}*0.34+\theta_{dsw-2}*0.23 + \theta_{dsw-3}*0.16+ \theta_{dsw-4}*0.11+ \theta_{dsw-5}*0.08+ \theta_{dsw-6}*0.05+ \theta_{dsw-7}*0.03$

Where θ_{dsw-1} is the daily swing of yesterday and θ_{dsw-2} the day before etc.

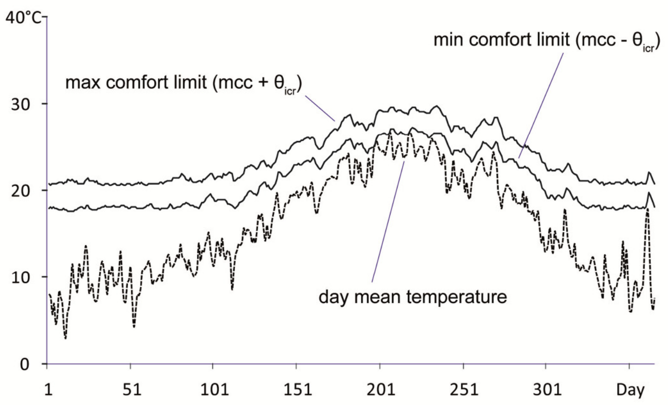

Fig. 4 – Comfort limits in terms of operative temperature and day mean along a typical reference year in Barcelona.

Results

To proof the usability of those findings we developed 3 prototypes of a generic room (4x5x3m) with one single exterior facade toward south, which are neither cooled nor heated with different characteristics:

Type 1 is composed by lightweight materials, large facade opening (also in the rear) with both a 1m deep fix and a movable protection against direct radiation. It is operated by constant cross ventilation

Type 2 has heavy materials and high thermal mass, the facade has a small opening protected against direct radiation. During the hot days it will be nocturnally ventilated and during the cold days diurnally ventilated.

Type 3 has a well insulated facade with medium opening and heavy material (not as much thermal mass as type 2). The room will be usually patch aired, except during the hot days when it is nocturnally ventilated.

We chose three cities to represent the three main climate groups: Singapore as a typical A- warm humid climate, Riyadh as a B- hot arid and Porto as a C- temperate and used them for a thermal performance simulation with combined with the three types of room proposed (Figure 5). The simulation was performed in PRIMERO, software based on Energy Plus.

The representation of the difference between the day temperature recorded (maximum and minimum) and the calculated comfort limit for each day turned out to be an effective mean for visual comparison and evaluation of the results.

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Note that only the parameters which directly influence the simulation results were considered. That explains that even for the A climate the high mass typology 2 has a better performance than typology 1 which is typical for that climate. Usually it would be necessary to consider the effects of air movement to have a more precise evaluation.

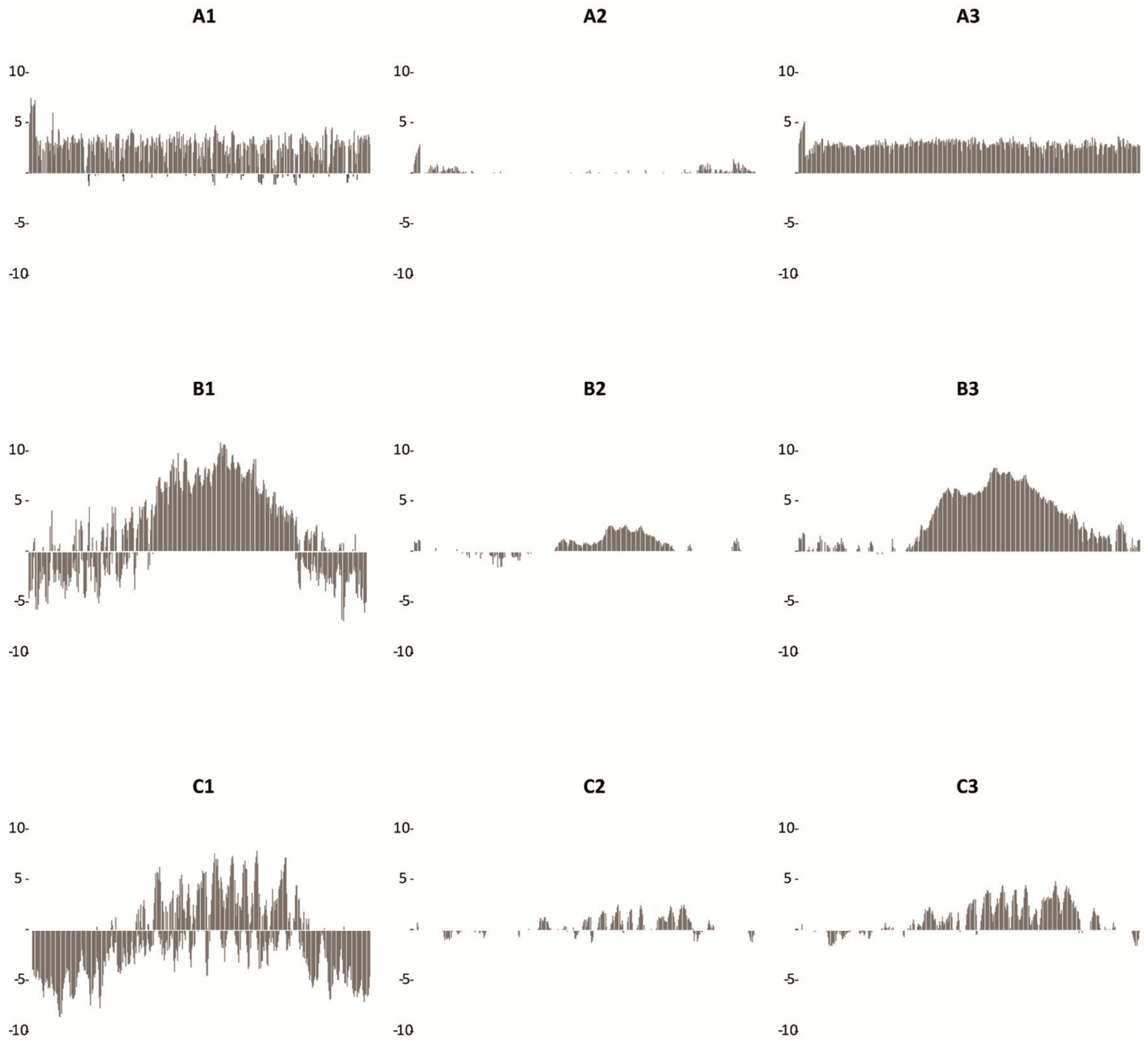

Fig. 5 – Results of the Thermal performance simulation with PRIMERO. Each diagram represents a generic room in a different climate during a typical reference year. The upper part represents the difference between the day max of the operative temperature and the comfort limit. The lower part of each graphic represents the difference between the day min of the operative temperature and the comfort limit.

Conclusions

This paper showed a new interpretation of the comfort range which is according to and can be well integrated to the current standards of the adaptive comfort theory.

Still there are some subjects, as the inclusion of the effects of air movement and the quality of the visualization of the results, to be developed in order to enhance the quality of the thermal performance evaluation.

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References

De Dear, R.J. Brager, G.S. & Cooper, D. (1998). Developing an adaptive model of thermal comfort and preference. ASHRAE RP-884 Final Report.

De Dear, R.J. (2011). Recent Enhancements to the Adaptive Comfort Standard in ASHRAE 55 - 2010. 45th Annual Conference of the Architectural Science Association, ANZAScA 2011. The University of Sydney.

ANSI/ASHRAE Standard 55R. (2004). Thermal Environmental Conditions for Human Occupancy. American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc.: Atlanta

CEN EN15251. (2007). Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics DIN EN 15251:2007-08. In Deutsches Institut für Normung e. V., B. B. V. G. (Ed), DIN., 10772 Berlin, Germany

De Siqueira, G. L. & Dietrich, U. (2013). Dividing indoor comfort limits by climate zones and describing it as a curve for the benefit of passive and low tech architecture de-sign. SB13. Universidade do Minho

Humphreys, M.A. (1978). Outdoor temperatures and comfort indoors. Building Research and Practice 6: 92-105.

Humphreys, M.A., Rijal, H.B. & Nicol, J.F. (2010). Examining and developing the adaptive relation between climate and thermal comfort indoors. Windsor, UK.

Nicol, J. F. & Humphreys, M.A. (2010). Derivation of the adaptive equations for thermal comfort in free-running buildings in European standard EN15251. Building and Environment, 45.

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Automatic quantification for waste management with bim models

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Abstract: *One of the fundamental aspects to consider when talking about sustainable construction is, without doubt, the correct waste management. In the RD 105/2008, where the production and management of Construction and Demolition Waste (CDW) is regulated, it is compulsory that the Assessment of CDW will contain at least an estimate quantification expressed in metric tons and/or cubic meters. Up until know, the quantification of the waste has been done either by estimates or manually through MTP derived and factorized quantification [I], which shall be used in this paper for its adoption too BIM models.*

The precision of this quantification system depends on the correct application of the model, the technical skills of the professional making the estimate, the correct definition and understanding of the construction project data, etc. Regarding this, we consider relevant to highlight that current BIM (Building Information Modelling) software such as Autodesk Revit ® and complementary software such as MEDIT ®, an Autodesk Revit Extension developed by BIM Iberica sl for the automatic QTO (Quantity Take Off) of construction projects, allow for the automatic quantification of building works and the quantification of the waste generated during the construction process.

To prove that this is absolutely possible, we have used Autodesk Revit® for modelling a prototype project, landscape, earthworks and foundations so to assign work items from the Andalucía Construction Cost Database Earthworks and Waste Management Sections to the model elements. On the other hand, we have manually quantified of these building works for analysing the differences, with results that vary in decimals of cubic meters that are irrelevant to the magnitudes of the prototype.

In consequence, not only we conclude that it is possible to automatically obtain the measurement of building works and the waste generated by them; but also, once the task of assigning the relevant work items to the model elements, an automatic and instant update measurement of the work sections and waste can be obtained.

RCD, BIM, REVIT, MEDIT

AUTOMATIC CUANTIFICATION OF CONSTRUCTION WASTE WITH BIM MODELS

1.- Introduction

One of the key aspects to consider in terms of sustainability of new buildings, is undoubtedly waste management. To reduce the environmental impact is essential to reduce the amount of waste generated in the process of building, this is why it is vitally important to have tools that allow us to know in advance, during the proyect phase, the expected amount of waste generated in construction phase, allowing us to make pre-construction decisions designed to reduce the amount of waste generated on site.

The system of construction waste of quantification with derived and factorized quantities based on the cost plan quantities, consist in transforming the quantities of the work elements in waste quantities produced by each one of them based on the assumption of the proportional relationship between the generated waste and the amount of product consumed, by using three coefficients named CR, CC and CT. The CR coefficient is used to measure the part of the element that is converted in waste, the CC coefficient is used to convert the measurement unit of the initial element into the measurement unit of the destination element and the CT coefficient is used to transform the measurement criteria of the original element to the measurement criteria of the final element. This process is developed in the publication "Presupuestación de obras" [I].

The method of weighted transfer measurement (MTP) has already been used successfully to determine the amount of waste generated from material resources consumed [II] in an article published by the authors, although the calculation has so far been using spreadsheet not associated with surveying; so the innovation presented in this article, with the BIM model is a great advantage in the construction sector, in terms of economy of time and closer to the reality of the cost of the work on project data.

This way of measuring where the link between the project information that is distributed across multiple documents and information of measurements is the architect planner of the same, is impractical because it doesn't allows to know the impact of changes in real time and traceability is almost impossible. In this regard, the BIM models are the next evolutionary step in determining the amounts obtained automatically allowing measurements of building elements and materials from a BIM [III] model with absolute traceability between the measurement lines and 3D objects or construction elements of the project.

Note that most of the articles related about BIM and measurements [III], [IV] ,[V], agree that BIM is the future of budgeting works however there is much research in terms of methodology and empirical analysis [VI]. It's necesary to analyze the information of virtual objects and associated information or be generated at the creation of each one of them to filter it and then organize it according to the rules and methods of quantification, measurement units, measurement criteria... It is therefore that determine the procedures for modeling and object creation are crucial to automatically generate reliable measurements according to established standards that apply.

Is necessary to elaborate BIM modeling procedures leading to obtain reliable measurements of the model. In many articles [III], [IV] ,[V] demonstrate the advantages of BIM models for obtaining the measurements, but does not speak any modeling procedures or integration analysis are performed on the model of the information required for each of the corresponding items this undoubtedly is a broad field of research that must be addressed.

2.- Methodology

To obtain the quantity of each element of the project that generates a residue and then apply the weighting and normalization coefficients (CR, CC and CT), we will rely on the breakdown of unit prices where the quantity of each basic element or auxiliary unit of measure indicated by the unit price , so that the amount of a basic or auxiliary element of the project is the sum of the results of multiplying the heading measurement for the amount of the basic unit of measure or unit element [I].

To perform the decomposition of each of the unit prices we shall establish as an hypotheses to determine of each minimum set of components that repeats continuously on a reference element, so that any error in the calculation of the amount of a component per unit of measurement, would imply a final error in the determination of the amount of waste generated elements.

In this sense BIM models have fundamental advantages over traditional graphic project information in drawing sheets. In a BIM model created for exemple with Autodesk Revit ®, we not only have geometry that makes up each of the elements of the project, but each one of these elements have associated information that is editable by the user. That is why thanks to BIM models we can obtain all kinds of information of any element of the model, allowing us to obtain the measurement of any basic or auxiliary element modelling by this unit of measure and measurement criteria. In this sense we are currently working on getting automatic measurements of the building elements of a prototype model according to the cirteria of the BCCA [VII], this work can automated with complementary tools to Autodesk Revit ® such as MEDIT by a suitable modelling process and parameterization of building elements.

After obtaining an accurate measurement of basic or auxiliary elements of the project, which we shall explain later and see an example performed on the prototype model, the next step is to apply the three standardizing coefficients CR, CC and CT for the amount of waste generated by each basic element or auxiliary as the final item of each of them, will also make an example with Revit Schedules for this.

The goal or what we propose is to develop a software tool to automatically and dynamically obtain from a BIM model at initial design phase waste quantities of each element of the project and the cost planning, enabling strategic decisions during the design phase of the project.

Before describing the procedure in order to obtain the automatic measurement with Autodesk Revit ® basic or auxiliary elements and the proportional amount of waste they generate, I will dedicate some lines to explain how information is organized in Revit. The hierarchical structure of any element model of a project in Revit would first be "category", second "Family" third "type" and finally "Elements model", ie any model element belongs necessarily to a type, which in turn belongs to a family which in turn belongs to a category. Note that Revit categories can´t be changed.

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To facilitate the understanding let´s take an example of a sliding window with dimensions of 1,20 m x 1,40 m, this model item category belong the windows, the window family of two sliding panels that specifies the general characteristics of all types of this window, and type specifying all dimensions of the sliding windows of two parts of the selected family. It is important to understand that each model element necessarily belongs to a Revit category, for schedules and material takeoffs of model elements are always grouped by categories, so we could create a material takeoff of structural concrete columns (Revit category), but it would not the amount of concrete for the entire project, it would be necessary to manually add quantities of concrete footings, beams, slabs, etc.

The commands and tools provided by Revit gives us to quantify building elements or materials of a project are "Schedule / quantities" and "Material Takeoff." With schedules / quantities we can get a list of all model elements belonging to a particular category and the size of each element, allowing also add columns to the table created by the user whose value corresponds to a formula determined by the volume, area, weight, etc ...

However, this tool may be insufficient to measure the materials of the work, since many of the building blocks of a model can have one or more materials, so a model item of wall shall be composed of different materials that comprise it, plaster, brick, insulation, mortar, etc.. To quantify these materials Revit offers the "Material Takeoff" tool that allows us to obtain the total amount of these materials for each model category, so the total amount of a material belonging to several categories, will be the sum of the amounts of material from each category.

3.- Resultados

Let's make a practical example of the prototype for measuring the volume of concrete and the volume of waste generated. First we have to model the structure of the project, specifically the columns. We will make the example of our prototype consisting of ground floor and first floor, with a reinforced concrete structure consisting of footings, columns, beams and horizontal slabs.

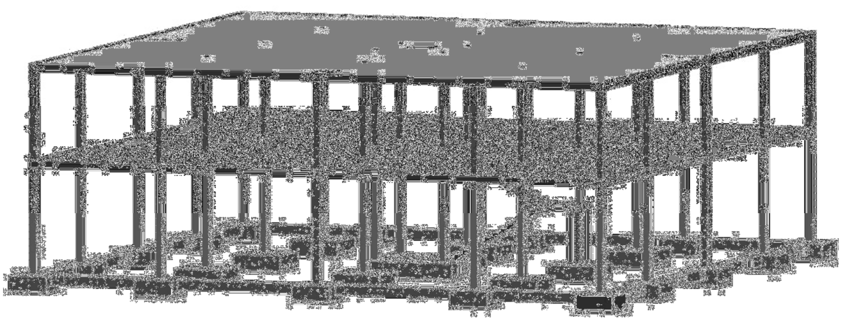

Image 1: 3D of the prototype structure proyect.

The procedure for obtaining the number of cubic meters of concrete pillars on the BIM model would begin using the material take off Revit command, which will show a dialog box where you must select the category to which the material belongs, remember that all material or building element must necessarily belong to a Revit category, in Figure 2 we can see the dialog box with the selected category.

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After selecting the category, we click accept and a new dialog with the properties of materials will appear where all the parameters needed to obtain the amount of concrete in structural columns that will be part of our schedule (Figure 3).

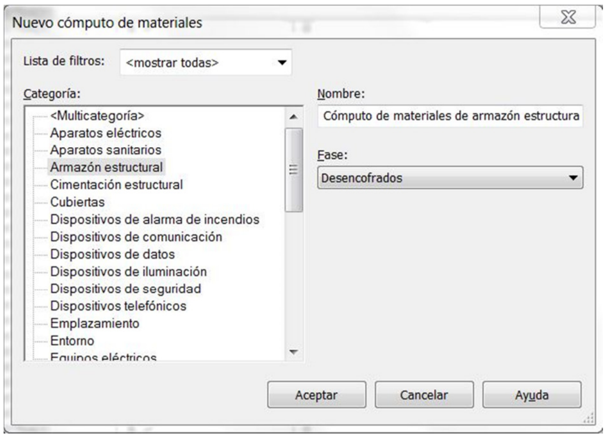

Image 2: Dialog box of new Revit Material take off.Dialog box of new Revit Materi 1

It must be noted that the "CR Concrete", "CC Concrete", "CT Concrete" and "Waste Quantity HA-25/B/20/I parameters are not Revit parameters, but user created parameters. To create new parameters you have to click on the Add Parameter button at the properties of the schedule dialog, Revit will show a new dialog showing parameter properties, here we define all the characteristics for the new parameter that we will create.

The project parameters will be Type parameters since they will be the same for all instances of the same type, we name the parameter and select number parameter type, it is essential to create calculated values from these values, we click on OK to finish and repeat the process we create parameters for CC and CT Concrete Concrete.

To create the field "Number of Waste HA-25/B/20/I" will click on the "calculated value" button in the dialog box to show us the Revit dialog "calculated value" where we can define the calculation formula by operations with fields that are part of the schedule. In picture 4 we can see the making of the formula for the Quantity field HA-25/B/20/I Waste. It is essential that the type corresponds to the unit of measurement of material with which we will operate. To enter the formula for calculating we select the button with three dots (...) to selec fields and symbols for operations similar to an Excel spreadsheet.

Once the defined parameters and the formulae for the calculated value corresponding to the amount of waste are created we shall accept and get a table with fields corresponding to the columns of the selected parameters (Image 3) and where the rows correspond to the amount of material concrete of each of the columns of the project. In picture 6 we can see an example of some rows of the table.

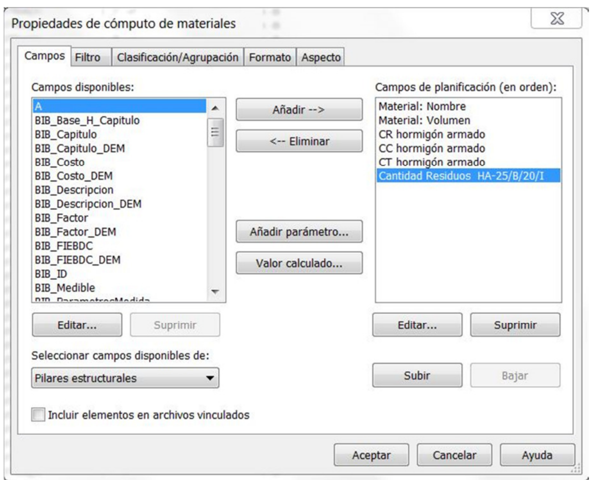

Image 3: List of fields for material takeoff for concrete pillars and amount of waste

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<HORMIGÓN HA-25/B/20/I EN PILARES>					
A	B	C	D	E	F
Material: Nombre	Material: Volumen	CR hormigón armado	CC hormigón armad	CT hormigón armado	Cantidad Residuos HA-25/B/20/I
HORMIGÓN HA-25/B/20/I, SUMINISTRADO					
HORMIGÓN HA-25/B/20/I, SUMINISTRADO	0.36 m³	0.05	1	1.1	0.02 m³
HORMIGÓN HA-25/B/20/I, SUMINISTRADO	0.36 m³	0.05	1	1.1	0.02 m³
HORMIGÓN HA-25/B/20/I, SUMINISTRADO	0.37 m³	0.05	1	1.1	0.02 m³
HORMIGÓN HA-25/B/20/I, SUMINISTRADO	0.36 m³	0.05	1	1.1	0.02 m³

Image 4: Schedule concrete take off from structural columns and generated wastes.

Therefore, the total amount of concrete pillars and waste generated correspond to the sum of the amounts corresponding to each model element, ie each row of the table. To calculate the sum of amounts listed in the table computing materials, we should mark on the dialog computational properties of materials, on the Format tab, activate calculate totals for "Material volume" fields and "waste Quantity HA-25/b/20/I and obtain the values as shown in the image 5 for the bottom of the table.

HORMIGÓN HA-25/B/20/I, SUMINISTRADO	0.3 m³	0.05	1	1.1	0.02 m³
HORMIGÓN HA-25/B/20/I, SUMINISTRADO	0.3 m³	0.05	1	1.1	0.02 m³
HORMIGÓN HA-25/B/20/I, SUMINISTRADO	0.3 m³	0.05	1	1.1	0.02 m³
	18.42 m³				1.01 m³

Image 5: Total concrete volume and corresponding waste generated volume.

At the image 4 and 5, we can see at the column designed by “Material Volume” which files corresponding to each pillar from de model, the summatory of all files is the total concrete volume in pillars of the model, and the summatory of the column denominated “Cantidad de Residuos HA-25/B/20/I” it`s the volume of waste generated from pillars execution.

To obtain the concrete HA-25/B/20/I total volume we have to create material takeoff for each Revit categories existing in the proyect, in this case the prototype contains Structural Framing for stairs and beams, Structural foundations for foundations, Structural columns and Floors for structural slabs. Such that the sum of the material quantities from each model category multiplied by their corresponding coefficients will give as the total waste quantity generated by each material of the project. Getting the following formulation of the research process derived from the method of MTP [1]:

$$Qr = \varphi(\sum Qmn) = \sum Qmn(CRm \bullet CTm \bullet CCm)$$

Qr = Waste quantity

Qmn = Material quiantity that becomes waste for each category

CRm = Coeffient for each material to measure the part of the basic element or auxiliary source which becomes waste.

CCm = Coefficient for each material for convert the measurement unit of the basic or auxiliary element source to the measurement unit for the destination building work item.

CTm = Coefficient for each material for transform the measurement criteria of the basic or auxiliary element in the source into the destination building work item.

We do not know of the existence of procedures for waste quantity in BIM models for comparative analysis, but we want to emphasize that this process is long and laborious, since it requires the manual creation of design parameters for each material, in addition to the inconvenience of manual aggregation of quantity waste per Revit categories. However this is a safe method that ensures the reliability of the results.

4.- Conclusiones

We can conclude that it`s possible to obtain from a BIM model atumaticly the quantification for waste management with Autodesk Revit®.

It would be usefully to create a complementary tool for Revit with weighthing coefficients for all materials that generate waste from the proyect. This tool sould be able to assigning these coefficients to each material returning in real time the total amount of proyect´s materials and waste generated allowing designers to make decisions for reducing waste generation during the building construction.

5.- References

(I) Ramírez de Arellano Agudo, A. (2010) *Presupuestación de obras*. Sevilla. Secretariado de publicaciones Universidad de Sevilla

(II) Mercader Moyano, P. & Ramírez de Arellano Agudo, A. (2013) *Selective classification and quantification model of c&d waste from material resources consumed in residential building construction.Vol. 31, issue 5. Waste Management & Research Editorial.*

(III) Royal Institution of Chartered Surveyors. (2014). How Can Building Information Modeling [BIM] Support The New Rules Of Measurement [NRM1]. www.rics.org

(IV) Forgues, D., Iordanova, I., Valdivesio, F., & Staub-French, S. (2012). Rethinking the Cost Estimating Process through 5D BIM: A Case Study. Paper presented at the ConstructionResearch Congress (CRC), Purdue University, USA.

(V) Jiang, X. (2011). Developments in Cost Estimating and Scheduling in BIM Technology. Northeastern University.

(VI) Olantunji, O.A., Sher, W., and Gu, N. (2010). Building information Modeling and Quantity Surveying Practice. *Emirates Journal for Engeering Research*, 15 (1): 67-70.

(VII) Base de Costes de la Construcción de Andalucía, www.juntadeandalucia.es.

ISBN: 978-84-697-1815-5

(i) http://www.akhbarak.net/articles/14759210 ,Access date 15/5/2014.
(ii) Tang, T. (2012) Sustainable buildings: smart, green and people-friendly. The College of Estate Management CEM . Occasional Paper Series United Kingdom .
(iii) http://www.futureagenda.org/pg/cx/view#415 ,Access date 12/4/2014.
(iv) Nikolaou,T. et al (2004)Introduction to Intelligent Buildings, Intelligent Buildings Handbook. chapter 1. Athens.
(v) http://www.abb.com/knx , Access date 18/4/2014.
(vi) Schittich, C.(2003) Solar Architecture ,Strategies .Visions .Concepts .BirKhauser .Basel.
(vii) Hendrson,H. (2012) Becoming a Green Building Professional. John Wiley& Sons, Inc. USA.
(viii) Hight, C. & Perry, C.(2006) Collective Intelligence in Design. John Wiley & Sons. London.
(ix) Nikolaou,T. et al (2004) P. ref.
(x) http://cleantechnica.com/2013/11/12/smartlight-set-change-way-use-energy/ ,Access date 20/4/2014.
(xi) http://www.bicsi.org/uploadedfiles/pdfs/presentations/region_events/Northeast_LaurelMD_03-14-13/BuildingIntelligentBuildings.pdf ,Access date 28/4/2014.
(xii) http://howtobuildit.org/2013/10/02/ho-to-install-a-bathroom-sun-tunnel/,Access date 12/4/2014.
(xiii) http://blog.heatspring.com/how-can-i-design-geothermal-systems-a-4-step-guide-to-designing-geothermal/
(xiv) http://www.arabcont.com/projects/ ,Access date 28/4/2014.
(xv) http://www.healthcaredesignmagazine.com/article/childrens-healthcare-21st-century-egypt
(xvi) http://www.evolveea.com/work/hsbc-cairo,Access date 18/7/2014.
(xvii) http://www.zawya.com/story/ZAWYA20100602111206/ ,Access date 18/7/2014.
(xviii) Wang, S.(2010) Intelligent Buildings and Building Automation. Spon Press. London.
(xix) Osso,A. et al (1996) Sustainable Building Technical Manual. Public Technology Inc.USA.
(xx) Poirazis, H. (2004) Double Skin Facades for Office Buildings. Department of Construction and Architecture, Division of Energy and Building Design. Lund University, Lund Institute of Technology, Lund.
(xxi) Karatasous,S. & Santamouris,M. (2004) Application of Intelligent Building evaluation matrix tool in case studies. Intelligent Buildings Handbook. chapter 5 .Athens.
(xxii) Phillips, D. (2004) Daylighting ,Natural Light in Architecture. Architectural Press. Oxford.
(xxiii) Stano, A. & Hawthorne, C. (2005) The Green House, New Direction in Sustainable Architecture. Princeton Architectural Press. New York.
(xxiv) Williamson, T. et al (2003) Understanding Sustainable Architecture .Spon Press. New York.
(xxv) Croome , D. (2004) Intelligent Buildings Design, Management and Operation .ASCE Press . Alexander Bell Drive . Reston . USA .
(xxvi) Ritter, A. (2007) Smart Materials in Architecture. Interior Architecture and Design. BirKhauser Publisher. Berlin.
(xxvii) Addington, M. & Schodek, D.(2005) Smart Materials and New Technologies .Architectural Press .Elsevier. New York.
(xxviii) Williams, D.(2007)Sustainable Design ,Ecology ,Architecture ,and Planning. John Wiley & Sons, Inc. New Jersey.
(xxix) Fouda, A. (2005) Energy code and its relationship to the building's outer envelope between theory and practice with special mention to the Egyptian Energy Code. Master Thesis. Faculty of Engineering. Cairo University. Egypt .
(xxx) Al-Abbasi, Sh. ,(2011)Energy Conservation in Residential Buildings Using Green Architecture Principals. Master thesis. Cairo University. Cairo, Egypt.

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Technological implants for sustainable autonomous upgrading of informal settlements in Cairo-Egypt

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Abstract: *Sustainable development is constantly being challenged by rapid unplanned and uncontrolled informal developments. While these are the people's interventions to fulfil their basic needs; they however, bear serious social, economic, and environmental implications and challenges. Currently, two thirds of Greater Cairo's 20 million inhabitants live in informal areas. This figure is expected to dramatically increase, exacerbating the already complex situation, if no real integral measures and solutions are implemented.*

This paper presents a preliminary study that challenges the regualr means of addressing informal developments - since these have proven unsuccessful over the years. The paper argues that the socio-economic triad of home, work, and mobility should be intertwined to create a nucleus for an integrated urban solution supported by a technology platform. This platform is based on a decentralised processing unit (dpu) - a module that can be 'implanted' into existing buildings and supported by an affordable adaptable building system (a^2bs). This is anticipated to allow for coordinated developments to take place, and hence, the self-evolutionary upgrading of informal settlements.

Keywords: autonomous upgrading, informal settlements, Egypt, technology

Background

Greater Cairo Region (GCR) is arguably the largest in Egypt, Africa, and the Middle East; and one of the most crowded metropolises in the world [1]. The consequences of which are multifaceted and complex due to the lack of coordination between the different urban components and settings. Urban developments in Egypt, in general, do not respond to the peoples' various needs, and further tend to overlook the underprivileged segment of the society, namely the elderly and people with impaired mobility.

While having a relatively young society with more than 60% of the population less than 30 years old - in comparison to Europe; Egypt is expected to witness a demographic change skewed towards older generations within 20-30 years from now, suggesting a decrease in growth from current 2.26 to 1.61 percent [2]. With the anticipation of more than 300,000 low income housing units are needed annually; and in order to mitigate the informal development phenomena; urban planning should be proactive and smart [3], and not only take into account the anticipated socio-economic and environmental change; but also make benefit of potential technological advancements. This, however, may require the application of new participatory techniques to ensure success.

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The inability of urban planning to respond to current as well as to future needs may contribute to increasing poverty and exclusion of certain segments of the society, thus allowing for chaos to overtake sustainable development; resulting in increase in slums and/or informal developments, lack of basic public services, and consequently may lead to the exploitation of the weakest [4].

Informal Developments in Cairo-Egypt

Cairo, in the 1950s could arguably be criticised as 'formal', abiding by the legislation which was introduced in the 1940s. The informal development phenomena emerged in Egypt in the late 1950s – due to increased rural-urban migration [5]; and has then increased drastically between 1967 and 1975 as a result of war, and the consequent Government failure to provide sufficient housing [2].

Informal developments can be defined as extralegal urban development processes which exhibit a complete lack of urban planning or building control [2, 5]. Informal areas arguably lack defineable street patterns, have no public spaces, and have rarely public services such as schools, clinics, or youth centres, etc. Furthermore, streets are very narrow (two to four meters wide); with small plots averaging between 80 to 150m^2; resulting in high population densities [2].

Cairo in 1974 was concluded to have already exceeded it's growth capacity and therefore, should be limited to 9.5 Millions [2].Currently, more than two thirds of Greater Cairo's 20 million inhabitants live in informal areas [6]. Generally, three major types of informal settlements could be identified in Cairo: these built on private former agricultural land, on desert land owned by the Government, or in deteriorated areas in old Cairo. Nevertheless, while these buildings lack building permits, the majority of which have adequate structural quality [2, 7, 8], and thus are not life threatening.

Many interventions were introduced in the last two decades to mitigate the wide spreading of informal developments such as e.g. denying water, sewerage, and electricity connections to those who do not have building permits. The resultant tension in 2006, however, led to the Governor of Cairo allowing any building in violation constructed before June 2006 access to utilities' connections. This, consequently led to the failure to mitigate informality which is fiercly continuing to date [2].

Informal developments, while are the people's solution to meet their own socio-ecoomic needs[2]; they undoubtedly overwhelm the infra-structure and services, that were not planned to accommodate such huge amount of the introduced (informal) households and commercial activities. While the traditional solutions and interventions addressing informal developments should be commended for their good deeds; they, however, tend to 'cosmetically' improve the situation within the informal developments; and are thus far from addressing the roots of the problem. Other interventions, follow a more radical action and call for relocating residents of informal settlements. This has also failed over the years, due to the fact that the areas of relocation do not satisfy people's socio-economic needs not least work and mobility.

The Housing Challenge

Egypt is currently facing a transitional period which should be regarded as an opportunity to embrace the sustainable development concept. Nevertheless, for three years now, there is no sign apparent for structured actions, rather individual uncoordinated efforts aiming to fulfill basic needss. This has led to the emergence of unprecedented phenomenon of chaos.

Chaos is manifested in buildings being built illegally and informally in any space that may be available with no attention to regulation, to building codes, or to health and safety measures. The illegal construction is now being carried out ‘under the eyes’ of everyone and in visible and vital areas in cities. The consequences of this blatant infringement of public and open spaces, has led - in certain areas – to the collapse not only of the buildings newly and illegally constructed, but also of the adjacent buildings, causing innocent people losing their lives [9].

Many initiatives were launched recently addressing the housing problem, informal settlements, and slums in Egypt. However, none of these seem to pay attention neither to the current needs of the affected people themselves, nor to potential socio-economic change in the society. These initiatives involve e.g. the Ministry of Housing initiative to provide one million social housing units, the initiative of the former prime Minister to allocate LE175 Million (Euro 24 Million) - [10, 11], and the civil society initiative to fundraise LE 1Billion to relocate informal slum areas, etc.

These different initiatives, although to be commended for their good intentions may exacerbate the problems rather than help solving them. This may be attributed to the lack of coordination among all the different initiatives. In addition, the different initiatives aim to build $36m^2$, $50m^2$, and $70m^2$ units (National Social Housing project), as “*this is what low income families need*” (Former Minster of housing to Al-Hayat al-youm talk-show, Feb, 2012). This top-down approach has always been the trend in the past 60 years and is seemingly continuing in the newly introduced initiatives, suggesting that no attention/nor intention is paid to the socio-economic nor to the technological advancement [12]; [13].

The Work Challenge

The unemployement rate in Egypt increased from 8% in 2008 to 12% in 2011 to around more than 13.4% in the first quarter of 2014 [14, 15]. The need to create around 560,000 new jobs annually for the unemployed and new entrants in the labour market in 2007 which increased to more than 750,000 in 2012 [16, 17] has further led to the expansion of the informal labour market phenomenon which is largely assoicated with informal housing developments. Informal jobs in Egypt have been estimated at 10 million before 2011[18] resulting in an informal economy ranging between 30-40% of the countries GDP to represent €20billion. Thus, trigered calls to formalise the informal economy[19].

The informal employment market introdued informal mixed use to the residential sector as well as its surroundings and even invading any open public spaces if existed [2]. This illegal transformation while providing work opportunities has serious drawbacks. These, include but are not limited to the overload on electricity, water and sewerge networks, noise, pollution, as well as its contribution to Cairo's infamous traffic congestions, to name but a few.

The Mobility Challenge
Another challenge that is strongly linked to both housing and work challenges is mobility within and around buildings. Traffic congestion represents a serious problem in GCR causing uncertainty in travel time, increased vehicles operating costs, poor air quality, poor public health, etc; which would therefore discourage any investments to take place in the region.

The failure of successive Governments over the past decades to provide decent and humane public transportation, and conseuquently the laissez-faire policy, resulted in the emergence of informal public transportation networks, which pay no attention to traffic regulations, environmental issues, or to public safety on the streets.

As a result of the rapidly increasing population and inadequate government responses; transportation conditions have deteriorated over the years and the transport system to manage demand from the growing urban population is argued to approaching the breaking point. The average travel speed on a business day may reach 15km/h and even less due to serious traffic congestions, poor passenger transport system, and high accident rate (more than 1000 deaths and 4000 injuries/year). The annual cost of traffic congestion could reach 4% of Egypt's GDP [1] [16]. An urban transport strategy was established to alleviate the problem, in collaboration with the World Bank, which gives priority to mass transport systems through establishing efficient, environmentally friendly, and affordable urban transport service and management in GCR[16]. Nevertheless, this strategy, did not seem to consider the elderly and those with impaired mobility. Furthermore, none of the strategy objectives could be evidenced on the ground.

The Life-Work concept
In light of the housing, employment, and mobility challenges, this paper suggests an all inclusive urban circle building on the "life-work concept". This is anticpated to alleviate congestions and further investigates efficient and sustainable means of mobility within and around buildings taking into account elderly and those with impaired mobility.

Life-Work balance is based on the separation and the equal division of work and private life, a recent endeavour, which differs from the integrated work and life common until the beginning of the 20^{th} century, where families all worked together [20]. The re-integration of life-work concept may be attributed to the work environment undergoing radical changes introducing new types of organisations; focusing on interdependence, building networks, and encouraging relations between workers, customers, and vendors. [20].

Since informality in Egypt 'forced' mixeduse acivities to the residential setting, it is suggested to formalise this through adapting the life-work concept to the Egyptian context. This, however, would need adaptation to current residential typologies. Public housing projects in Egypt typically consist of four to five storey walk-up blocks with two to four units per floor.

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They are usually arranged in geometric patterns within the site. In the 1980s one single attempt could be recorded, where a new housing concept was introduced, the artisant housing [hirafi] - standard aparment blocks, with the ground floors dedicated to workshops, whose owners and workers would live in the apartments above. This concept had arguably limited success and has since not been widely repeated [2]. Nevertheless, no reason was evidenced in extant literature to such limited success.

The technology as a nuculeus for an all inclusive urban approach
In order to technolgocially achieve the nucleus of life-work concept, the soft socio-economic requirements need to be translated into hard technological solutions for affordable housing that is scalable to accommodate future needs vis-a-vis home, work, mobility, energy etc.

The suggested technology strategy is based on introducing a concept of a decentralised processing unit (dpu) which repesents the core/heart of a building (Figure1). The dpu is the technological key element of the building system which serves as the platform of the building [21]; [22]: a basic framework or a basic structure that contains the core functions of a product [23]. The dpu's subsystems would accomdoate: housing (core for refurbishing or upgrading existing housing stock in informal areas), work (mini production unit or mini office for working at home), mobility (e.g. docking station for e-vehicles), and energy (alternative/renewable energy technology) etc..

The dpu-nucleus with its subsystems will be integrated into a building kit – an affordable adaptable building system (a^2bs). This kit design will be tailored to suit the investigated structures in informal housing. The aim is to allow the a^2bs to grow or evolve over several generations within an existing informal settlement so that it gradually replaces the old unstructured environment by a more structured one that provides better tools, technologies, and living conditions for the residents (Figrue1). This requires, the provision of an infrastructure that would allow a modular, adaptable, and scalable unit, based on the open building approach [24, 25]; [26], [27], [28]; [29]; [30].

In prefabrication, the concentration of functions and complexity in a certain part of a building allows for efficient mass production of the technological core element. Hence, resulting in reduced production cost; which allows the delivery of technologically advanced buildings at a reasonable cost.

The a^2bs through its sub-systems can be easily adjusted to changing requirements of the users and inhabitants as family structure changes. For example, the structural subsystem would have the longest life cycle e.g. 100 years, while the exterior envelope subsystem could be exchanged every 10-20 years according to energy requirements. In the same context, infra-structure and HVAC systems could also be exchanged every 5-15 years. In addition, the interior system could be exchanged according to changing family structures like single, couple, and couple with one child or more, with parents, or with mobility impairment etc. Further adaptation of the system could be triggered by the new life-work coordination such as personal or home fabrication (life-work concept). In this context each family could have their own 'fabricator' at home and delivers components to larger assemblies. While, the life-work concept may provide an opportunity to solve the increasing unemployment rate, it would also help mitigate traffic congestions and help increase family ties and create value added products to the economy.

Conclusion

This paper represents the preliminary work of an ongoing research project which challenges the traditional means for mitigating informal developments. Building on the life-work concept, the triad of home, work, and mobility are advocated to be intertwined and addressed in all planning or upgrading strategies. This could be supported through a technological solution which needs to be adapted to the Egyptian context. A modular mass produced decentralised processing unit (dpu), a core that can be implanted into existing developments, and can be adaptable to future socio-economic needs. With the support of an affordable and adaptable building system (a^2bs), future developments could be controlled and hence, gradually upgrade informal areas. The suggested solution is anticipated to alleviate the unemployment rate, legitimate the mixed-use phenomenon; and thus, lessens traffic congestions. Furthermore, this solution would allow adaptability and scalability to accommodate future socio-economic needs.

References

[1] ECORYS, *Cairo Traffic Congestion Study*, ECORYS Nderland BV and SETS Lebanon, Editors. World Bank and Government of Egypt: Cairo. 2010.

[2] SIMS, D., *Understanding Cairo: The logic of a city out of control*. Cairo: The American University Press. 2010.

[3] REINVENTING PLANNING, *Reinventing Planning: A new Governance Paradigm for managing human settlements*. 2006.

[4] UN-HABITAT, *Urban Planning best practices on creating harmonious cities*. 2007.

[5] FAHMY, N., ***A Culture of Poverty or the Poverty of a Culture? Informal Settlements and the Debate over the State-Society Relationship in Egypt*** Middle East Journal. **58**(4): 2004, pp. 597.

[6] GOLIA, M., *Cairo City of Sand*: The American University in Cairo Press, Egypt. 2004.

[7] BEN NEFISSA, S., *Cairo's City Government: The ciris of local administration and the refusal of urban citizenship*, in *Cairo Contested: Governance, Urban Space, and Global Modernity*, Singerman, D., Editor., The American University in Cairo Press: Cairo. 2009.

[8] UN-HABITAT, *The Challenge of Slums*, in *Global report on Human Settlements*, Programme, U.N.H.S., Editor., 2003.

[9] DAILY NEWS *Two dead in Alexandria building collapse*. 2013.

[10] ABU-AL-KHAIR, W. *Government and grassroots organisations focus on eradicating Egyptian slums*. 2011.

[11] EGYPT INDEPENDANT *Government allocates LE175 million for development of slums*. 2012.

[12] MINISTRY OF HOUSING UTILITIES & URBAN DEVELOPMENT (MOHUUD) and AND JAPAN INTERNATIONAL COOPERATION AGENCY (JICA), *The*

ISBN: 978-84-697-1815-5

Strategic Urban Development Master Plan Study for Sustainable Development of the Greater Cairo Region in the Arab Republic of Egypt. 2008.
[13] MAISEL, J.L., *Toward inclusive housing and neighborhood design: A look at visitability.* Community Development. **37**(3): 2006, pp. 26-34.
[14] CAPMAS, *Unemployment rate and annual estimates of labor status by educational status and sex in 2011*. Central Agency for Public Mobilization and Statistics. 2014.
[15] BANK, W., *Egypt Overview*. World Bank. 2014.
[16] KOUEDI, H.E. and MADBOULY, M., *Tackling the Shelter Challenge of Cities: Thinking it through together*. General Organization for Pysical Planning, Ministry of Housing, Utilities and Urban Development
World Bank: Cairo. 2007.
[17] AFRICAN DEVELOPMENT BANK GROUP, *Egypt's Government commits to creating 750000 New Jobs under the auspices of State Committee dedicated to Micro-projects and Youth Employment.* 2012.
[18] EL-RIFAE, Y., *Egypt's Informal Economy*. 2014 [
[19] INDEPENDENT, E., *Informal economy presents challenges, but also opportunities*. 2012.
[20] KALLASH, S. and KRUSE, M., *The future of work and work-life balance 2025.* Futures. **44**(7): 2012, pp. 678-686.
[21] SCHMIEDER, M. and THOMAS, S., *Platformstrategien und Modularisierung in der Automobilentwicklung*. Aachen: Shaker Verlag. 2005.
[22] SÜBA. *SÜBA Bauen und Wohnen; Karlsruhe GmbH*. 2014 [cited Access Year Access Date, Available from: http://www.sbw-karlsruhe.de/.
[23] LINNER, T., *Automated and Robotic Construction: Integrated Automated Construction Sites*, in *PhD Thesis*. Technical University Munich: Munich, Germany. 2013.
[24] HABRAKEN, N.J., *The Structure of the Ordinary - Form and Control in the Built Environment*. Cambridge: MIT Press. 2000.
[25] KENDALL, S. and TEICHER, J., *Residential Open Building*, International Council for Building Research Studies (CIB), Editor: London. 2000.
[26] LAWRENCE, T.T., *Chassis + Infill: A Consumer-Driven, Open Source Building Approach for Adaptable, Mass Customized Housing*, in *Massachusetts Institute of Technology*: MSc. Thesis. 2001.
[27] LARSON, K. and STEPHEN, I., *MIT Open Source Building Alliance - A house_n initiative, Position Paper*. House_n Research Group, Department of Architecture, MIT: Cambridge. 2005.
[28] INTILLE, S., LARSON, K., BEAUDIN, J.S., NAWYN, J., MUNGUIA TAPIA, E., and KAUSHIK, P., *A living laboratory for the design and evaluation of ubiquitous computing technologies. Conference on Human Factors in Computing Systems*. NY
ACM Press
2004.
[29] LINNER, T. and BOCK, T., *Evolution of large-scale Industrialization and Service: Innovation in Japanese Prefabrication Industry.* Journal of Construction Innovation: Information, Process, Management. **12**(2): 2012, pp. 156-178.
[30] GEORGOULAS, C., LINNER, T., KASATKIN, A., and BOCK, T., *An AmI Environment Implementation: Embedding TurtleBot into a novel Robotic Service Wall*. in *Proceedings of 7th German Conference on Robotics*. Munich, Germany, 2012, VDE Verlag.

ISBN: 978-84-697-1815-5

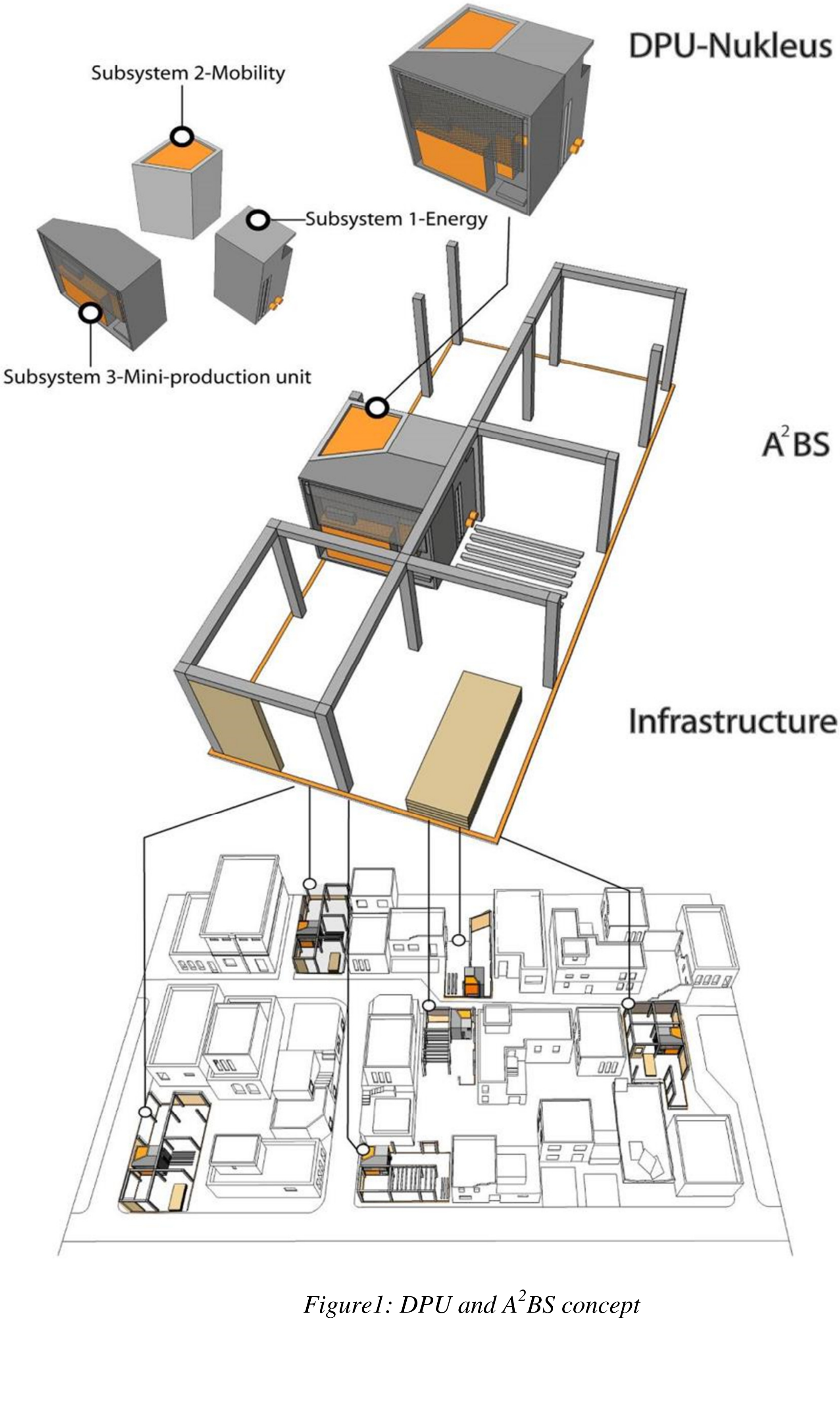

Figure1: DPU and A^2BS concept

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Sustainable community and neighbourhood regeneration and development. Experiences from the approach and implementation of VTT's EcoCity concept.

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Abstract: *VTT has a long history of research on different aspects of sustainability of the built environment. Findings from and knowledge gathered in EcoCity related projects in the European context led into the second phase of our neighbourhood development projects in Finland, but also in China, Russia and Kenya. The third phase in the evolution of VTT's EcoCity concept started after the previous World Sustainable Building Conference that we hosted in Helsinki in 2011 where we expanded the focus of the international research community to consider people and their needs also in the developing world which led to new projects in Tanzania and Libya as well as our ongoing activities e.g. in Zambia, Egypt and Colombia. This paper describes our approach to and experiences from developing and implementing VTT's EcoCity concept for sustainable community and developing countries.*

Keywords: ecocities, sustainable built environment, neighbourhood development, emerging economies, developing countries

Introduction

The evolution of VTT's EcoCity concept for sustainable community and neighbourhood regeneration and development in Europe, in emerging economies and in the developing countries (Antuña et al. 2013a) are shown in Figure 1.

Among the main challenges addressed by VTT's EcoCity concept (Huovila et al. 2012a) are:

- climate mitigation and climate adaptation
- sustainable urbanization
- affordable housing
- integrated planning and funding availability
- capacity building for local solutions and services
- citizen empowerment and participation, job creation
- cross-cutting themes: gender issues, etc.

To respond to these challenges, the concept is built around a strong collaboration with reliable local partners in order to answer to local needs previously identified and discussed with them. The flexibility of EcoCities' approach allows the implementation of expert solutions depending on local conditions and customized to varying socio-economic realities worldwide.

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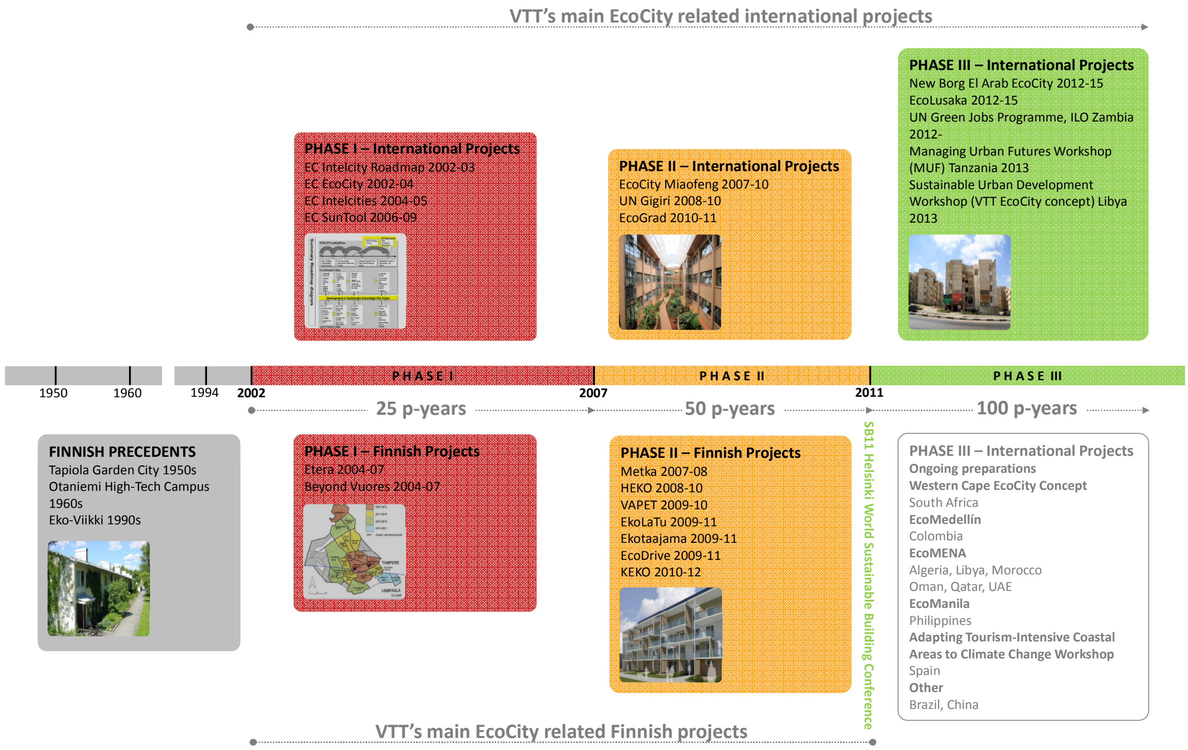

Figure 1. VTT's EcoCity Roadmap (Pekka Huovila & Carmen Antuña, VTT 2013)

VTT's EcoCities' approach developed to respond to the abovementioned challenges in collaboration with local partners can be summarized as follows:

- best combination of technologies and services that form sustainable solutions providing the users and inhabitants a high quality of life and indoor and outdoor comfort;
- applicable EcoCity solutions depend on local conditions and need to be customized to socio-economic realities;
- there is not one solution that fits all, but a number of possibilities that need to be studied to find the right solution for each case;
- requires knowledge of local traditions, perceptions, available materials and competent partners.

This paper describes shortly approaches to VTT's EcoCity capacity building projects in Egypt and Zambia and key findings from VTT facilitated sustainable urban development seminars or workshops held in Finland, Tanzania, Libya, United Arab Emirates and Colombia.

Capacity building for EcoCities in Egypt and Zambia

EcoNBC, EcoCity capacity building in New Borg El Arab City in Egypt and EcoLusaka, sustainable education for the construction sector in Lusaka, Zambia are both ongoing one-to-one projects built around capacity building.

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The project’s main objective is to increase the knowhow of the Egypt-Japan University of Science and Technology (E-JUST) in the field of EcoCity planning. Raised awareness of local stakeholders is another objective. As a case study for these activities, a feasibility study will be made for turning NewBorg El Arab City into an EcoCity. An EcoCity roadmap for Egypt will also be done in the course of the project. The work is carried out in close collaboration between Egyptian experts at E-JUST and VTT. Activities like residents surveys, state of the art analysis, establishment of the energy efficiency office, student competition, workshops and seminars, training sessions, study tours, etc. will be arranged during the project. (Hedman et al. 2013)

The overall objective of EcoLusaka project is to increase the supply of qualified workers capable of using sustainable construction tools and techniques in response to the growing demand within the Zambia construction sector. In order to support this overall objective, EcoLusaka will strengthen the capacity of the local partner, Thorn Park Construction Training Centre to provide education on sustainable construction and disseminate the results for wider use in Zambian construction sector. (Antuña et al. 2013b)

Lessons learned from Seminars and Workshops on sustainable urban development
VTT organized in conjunction with SB11 Helsinki World Sustainable Conference in October 2011 a seminar called African Star (Huovila et al. 2012b). It showed a panorama of different initiatives around the African continent towards a more sustainable development covering social, economic and environmental aspects (Huovila et al. 2012c).

Figure 2. African Star seminar at SB11 Helsinki was supported by a film stream of the topic from the region (Pekka Huovila & Carmen Antuña, VTT 2011)

The topics covered Women's Bank activities, Technology for Life Projects in Africa, Innovation policies for African governments, examples from Mwanza, Tanzania and Mozambique together with sustainable green life style approach from South Africa. The discussion followed on how to raise awareness of the main challenges Africa will face in the coming years and on possible ways to address them.

Managing Urban Futures workshop was held held in Tanzania in March 2013 to support sustainable development in East and Southern Africa. It had active participation of key stakeholders from Ethiopia, Uganda, Kenya, Tanzania, Rwanda, Zambia and South Africa with invited mentors from the Philippines and Thailand. VTT facilitated two days there based on a Mwanza case study focused on urban and environmental planning, waste management and sanitation, participatory approach and communities, housing and informal settlements.

Figure 3. Managing Urban Futures Workshop in Tanzania (Photo: Pekka Huovila)

Sustainable Urban Development Workshop was held in June 2013 in Libya by local partners from National Authority for Scientific Research (NASR), Ministry of Housing and Utilities (MHU) and Libyan Urban Planning Society (LUPS) together with VTT including visits from Tripoli to Sabrata and Yefren. The urban planning situation in Libya calls for innovative concepts as, sustainable urban planning has an important role to play in guiding their future urban strategies. Active urban planners, researchers and academicians in Libya can benefit greatly from discussions of research and innovation services provided by experts including, sustainable city development and redevelopment, designing of sustainable buildings, innovative programs on water resource use and waste disposal practices, and many other aspects of assessing urban ecological efficiency.

Libyan development priorities in the field of sustainable urban development were identified:

- urbanization trends and pressures in Libya
- sustainability challenges and choices in technical infrastructure development
- urban transport

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- water supply and waste management
- housing infrastructure development.

Figure 4. Refurbishment challenges in Tripoli, Libya Photo: Pekka Huovila)

The workshop on Sustainable Urban Development organized jointly by the Ministry of Environment and Water of the United Arab Emirates and VTT in Dubai in December 2013 reviewed the present situation and main challenges in the region in light of UAE's Green Growth program (UAE, 2013). The topics highlighted in the program are green cities, green technology, green life and green energy, but also green investment and climate change.

During 7th World Urban Forum (WUF7) organized by UN Habitat in Medellín, Colombia, in April 2014, VTT hosted a side event on sustainable community and neighbourhood regeneration and development (WUF7, 2013). Such an event provides a platform for governments, partners, civil society organizations, private sector, community representatives, international and national organizations, academia, international and regional finance institutions, and other entities to showcase or present their latest innovations or best practices. The well attended session where VTT shared their experiences from EcoCity projects in emerging economies and developing countries with various stakeholders raised considerable interest and vivid discussion.

Also in the context of WUF7, CRAterre, INBAR, Habitat for Humanity, and University of Cambridge hosted a networking event to discuss key tools for assessing sustainability and share knowledge in the affordable housing sector. In that occasion, a global rating tool was presented, co-produced by UN Habitat and CRAterre with the collaboration of other international partners including VTT who is a founding partner of the recently launched Global Network for Sustainable Housing, under the auspices of UN-Habitat (GNSH, 2013).

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Figure 6. Public transport reaching informal settlements in Medellín, Colombia (Photo: Pekka Huovila)

Figure 7. UN Habitat Sustainable Housing Rating tool (Source: CRAterre)

Discussion and conclusions

Our seminars and facilitated workshops have enabled various stakeholders to identify, analyze, discuss and propose solutions for the problems encountered. VTT's EcoCity concept, as localized and implemented in different continents and contexts, seems to provide a proper framework for sustainable community and neighbourhood regeneration and development in the industrialized world as well as in emerging economies and developing countries. It is based on environmental, social and cultural and economic sustainability, customized together with local partners, and flexible enough to integrate key aspects identified through participatory processes. It covers applicable technologies and services to improve quality of life and climate mitigation without forgetting job creation green jobs), particularly for the youth, and affordability.

The valuable experience accumulated at VTT after a long list of relevant related projects helps the local partner in the diagnosis of the situation and decision making process as well as in writing “bankable proposals” that are sound in terms of funding opportunities.

References

Antuña, C., Huovila, P. & Ruuska, A. (2013) VTT’s EcoCity concept for sustainable community and neighbourhood regeneration and development. *SB13 Manila Conference Proceedings*. Sustainable Buildings, Infrastructures and Communities in Emerging Economies, 25-27 November 2013 Manila, Philippines.

Huovila, P. & Antuña, C. (2012) ECOCITIES, VTT's concept for sustainable community and neighbourhood regeneration and development. *Proceedings of the 2nd World Sustainability Forum WSF-2012),* 1 - 30 November 2012, Sciforum Electronic Conferences Series.

Hedman, Å., Huovila, P., Tuominen, P., Reda, F., Antuña, C., Jantunen, J., Pajula, T., ElMahgary, Y., El Shazly, A., Tawfik, A., Shahin, M., Hamza, A., Gamal, M. (2013). *SB13 Cairo Proceedings*. Democratic Transition and Sustainable Communities: Overcoming Challenges through Innovative Practical Solutions, Sustainable Building Conference, Cairo, 5-7 November 2013, Egypt.

Antuña, C., Huovila, P., Chitenge, B, Mwansa, J. & Mwanza. K. (2013) EcoLusaka project: sustainable education of the construction sector in Lusaka, Zambia. *African Newsletter on Occupational Health and Safety*. Finnish Institute of Occupational Health. Vol. 23, No. 68-71, 2013.http://www.ttl.fi/en/publications/electronic_journals/african_newsletter/Documents/AfricanNewsletter3_2013.pdf *site visited 26 May 2014*

Huovila, P. & Antuña, C. (2012) Review of the SB11 Helsinki World Sustainable Building Conference. *Smart and Sustainable Built Environment*. Emerald Group Publishing Limited. Vol. 1 2012) No: 2, 206 –214.

Huovila, P. & Antuña, C. (2012) Lessons from SB11 Helsinki. *Building Research & Information*. Vol. 40 (2012) No: 5, 539 – 544.

UAE (2013) UAE Green Growth Strategy. PowerPoint presentation, 13 slides. 28.1.2013.

WUF7.(2013)http://worldurbanforum7.org/Media/Default/PDF/WUF7_VTT%20EcoCity_Side%20Event_EN.pdf *site visited 26 May 2014*

GNSH (2013) www.gnshousing.org *site visited 26 May 2014*

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The influence of the Mediterranean climate on vernacular architecture: a comparative analysis between the vernacular responsive architecture of southern Portugal and north of Egypt

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Abstract: *Mediterranean vernacular architecture was developed not only with respect to environmental and climatic factors but also with respect to culture, traditional construction materials and morphology. Despite the far distance between Portugal and Egypt, it was possible to find similar vernacular strategies under the influence of the Mediterranean climate and both Roman and Arab cultures. The paper adopted an explanatory qualitative analysis and comparative synthesis methods for vernacular passive and climatic responsive strategies for two regions. Covering from site planning, building design till building materials used through considering topography, resources, historic and cultural aspects. The outcomes of this research allow for understanding how different passive solar strategies and the use of natural energy sources can contribute to achieve appropriate indoor comfort conditions for contemporary practice. The paper draws a set of recommendations for more in-depth quantitative survey and energy efficiency measurements in Mediterranean climate.*

Keywords: Climatic responsive, vernacular architecture, Mediterranean climate, Roman and Arab cultures, comparative analysis, Sustainable Building

1. Introduction

The wide area of the Mediterranean basin, with a plurality of territories and the presence of numerous cultures, provided a rich variety of architectural manifestations. The Mediterranean vernacular architecture we value nowadays as a model for sustainable and energy efficient architecture building product, is in fact the outcome of a cumulative effort to sustain a living in the relation with local constraints and the available resources. Therefore, vernacular architecture is a type of construction that should be studied from sustainability point of view, since the strategies that are now the basis of sustainable construction are derived from aspects and characteristics of this type of architecture [1].

In this context, several studies have revealed the good thermal performance of vernacular buildings in the Mediterranean climate context using both qualitative analysis and quantitative measurements for building performance, emphasizing the benefits of using local materials [1]–[4]. The approaches used in vernacular constructions to mitigate the effects of climate are usually low-tech and not very dependent on non-renewable energy. Moreover they do not require special technical equipment, which makes them suitable for contemporary passive building design [5]. However, some studies have shown challenges in adopting such techniques for contemporary applications [6] due to several limitations owing to changing weather condition and valuable resources along the years. From here, this paper aims to highlight the need to learn from the vernacular know-how and methods in order to rehash an optimum adaptation of contemporary buildings to climate, environment and culture.

2. Methodology

The paper is applying a qualitative approach through explanatory qualitative analysis and comparative synthesis methods for vernacular climatic responsive strategies used in Mediterranean vernacular architecture. The application was on cases/examples from southern part of Portugal and northern part of Egypt. The comparative analysis was based on systematic comparison of different passive climatic responsive strategies with focus on passive cooling strategies to understand similarities and differences. The analysis was the guidance for lessons learnt for the further possible contemporary application and the recommendation for qualitative survey for more robust evaluation for such passive strategies.

3. Characterization of the Mediterranean climate in Southern Portugal and Northern Egypt

The Mediterranean climate is a type of climate mainly from the regions in the Mediterranean Basin, but it also can be found in other parts of the world. The inland southern Portugal has a Mediterranean climate, sub-type Csa according to Köppen climate classification, hot and dry during summer [7]. In summer the mean values for maximum air temperature vary between 32-25°C, reaching sometimes maximum temperatures of 40ºC or 45ºC, being July and August the hottest months [7]. The annual average rainfall is below 500 mm, being July the driest month (below 5 mm) [7].

The Egyptian land lies within the hot desert climate (BWh) according to Köppen climate classification. The climate in northern part of Egypt is a hot Mediterranean climate that is quite different from the climate in the rest of desert areas of Egypt. Prevailing winds from the Mediterranean Sea greatly moderate the temperatures of the northern coastal line, making the summers moderately hot and humid, while the winters moderately wet and mild [8]. Temperatures range between a minimum monthly average of 9.5 °C in winter and 23 °C in summer, while a maximum monthly average of 17 °C in winter and 31 °C in summer [8]. The annual average rainfall is around 200 millimeters [8].

4. Climate-responsive strategies used in Mediterranean vernacular architecture

Mediterranean vernacular architecture is known and recognized by being a practical, effective, sustainable climatic and environmental responsive building outcome [9]. In the past, when energy was not readily available and active systems did not exist, builders had to experiment and develop passive ingenious systems that optimize indoor comfort and respond to particular human needs and climatic conditions through the available resources [9]–[12]. Table 1 presents in a comparative way several climatic responsive vernacular strategies showing different adaptive passive solutions in Mediterranean regions in both countries.

Table 1. Climate-responsive strategies used in vernacular architecture from northern Egypt and southern Portugal

Strategy	Description	Figures	
		northern Egypt	southern Portugal

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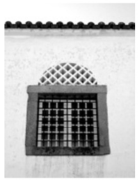
Urban layout and building form	• Compact urban layout reduces the number of surfaces exposed to the sun *(To the left map for Alexanderia, Egypt from [13]);* • Narrow streets and covered galleries protect pedestrians from harsh summer periods. • Building's form is compact and the presence of *patios* in urban areas is frequent. On orientation, buildings seek the south quadrant to maximize solar gains in winter and to reduce them during summer.	  	  
Shading and use of natural ventilation	• Proper shading for windows using screens (*mashrabiya)* or vegetation when heat gains are not desired. • The use of grids aims to foster cross air circulation in the building, ensuring privacy and thermal comfort;	 	 
Small openings	• Minimizing the size and number of openings reduces heat gains.		 
Evaporative cooling	• Fountains and pools, usually placed in patios and cloisters, serve to cool air by water evaporation.		
Use of vegetation	• Vegetation is useful to provide shade and to increase air moisture via evapotranspiration process, helping to cool the air streams before reaching the building.		
Materials and thermal mass	• The use of local materials, mainly earth and stone, is perfectly suited to local climate. Their good heat storage capacity stabilizes indoor temperature (that remain cooler during the day and warm at night).		
Buildings' colour	• The use of light-colours for the building envelope, and especially the roof which is the most exposed to the sun, aims to reduce heat gains by reflecting solar radiation.		

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5. Discussion
Despite the distance between Portugal and Egypt and their opposite position in the Mediterranean basin, it was possible to find commonalities regarding passive vernacular strategies used in both countries. They are mainly due to the influence of Mediterranean climate but also a reflection of a common Roman and Arab cultural influence. As shown in Table 1, the strategies used in the two regions, and their purpose, are very similar. Due to a climate with hot dry summers, these strategies are more oriented to a passive cooling purpose. Some of these strategies are discussed below.

5.1 Urban layout and building orientation
On the urban level, the use of a compact layout is more adequate for these regions with hot summer periods than modern orthogonal and wide grid street planning. A compact urban fabric provides more shade between buildings minimising heat gains in summer and in winter reduces internal heat losses. At street level, narrow streets and covered galleries integrated in buildings' structure are more confortable for pedestrians because they provide shade and reduce wind velocity specially during winter [14]. These sinuous streets act like "urban-patios", storing cool air during the night and promoting air crossing between streets during the day. In the morning, due to high thermal inertia, the walls and pavements of these streets remain colder than ambient air. Green public areas are also found useful to reduce the heat island effect and to increase comfort in urban space (green ground covers absorb 10% of radiation while a pavement absorbs 65% [14]).

Buildings orientation depends on several site conditions, like topography, so buildings seek the best orientation compromise. As shown in table 1, south quadrant-facing façades are the most common to receive less radiation during summer and more in winter. At the same time, east and west facing façades are avoided to minimise direct heat gains. In detached buildings the rear façade (without or only with a few openings) is oriented to the summer cool prevailing winds.

5.2 Passive cooling and natural ventilation
On buildings' scale, the more common passive cooling strategies are: i) the use of *patios*, to minimise sun-exposed surfaces, maximise shade and ventilation; ii) the use of vegetation in patios to increase the cooling effect of air; iii) the use of heavy thermal mass and dense building materials, like earth and stone, with high thermal storage capacity to balance temperature variations; iv) use of bright colours to reflect radiation.

Focusing on *Patios*, these are a special passive cooling building feature that is intrinsically related to Roman and Arab cultures. Frequently possessing vegetation and elements containing water, their presence has a great influence on buildings' microclimate. An experiment conducted in southern Portugal during summer showed that air temperatures in the *patio* always remained lower than those recorded for the city centre, with a maximum difference of around 9ºC during daytime [3]. Another study in Egypt showed that shaded *patios* recorded from 5 to 8 ºC difference than outdoor street temperature [15]. This is due to the effect of evapotranspiration and shade from plants and evaporative cooling of water.

Natural ventilation for overnight cooling is an important and useful passive strategy in a hot climate. Through the use of night flush effect using grids, like the *mashrabiya,* it is possible to

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promote air circulation inside the building, removing diurnal thermal loads and increasing thermal comfort, without compromising privacy and security levels.

5.3 Building envelope and building materials

The envelope is building's most exposed surface to solar gains. To reduce them, small window-openings (retreated into the façade to get more shade) and light colours are adopted. The colour applied on outdoor surfaces has a tremendous effect on reducing the impact of sun on facades and on the indoor temperature [16]. Thus, the traditional whitewash painting is an important element against extreme solar radiation, allowing a reflectance of about 90% of all the radiation received [14].

On the materials, stone and earth (mainly rammed earth and blocks) are the main building materials in both regions. The high mass that characterizes earthen and stone constructions allows them to respond appropriately to the scorching summer. Several studies mentioned the good heat storage of earth and stone (Table 2) and how they stabilize indoor temperature and moisture [17], [18]. It is discussed how traditional earthen and stone interiors remain cool during the day and release warmth at night, the opposite of concrete, a material that, traps and holds high temperatures unbearably [19], [20]. Another advantage is that earth and stone can be easily recycled, either by re-using old stone blocks or earth bricks as building material or returning earth to the soil to grow vegetation. The use of materials that came from the same local climate where they are applied has greater adaptability, economical and increased durability. Moreover, they have less embodied energy and less environmental impacts than other conventional materials (Table 2).

Table 2. Properties of some vernacular and conventional building materials (source: [14], [21], [22]*)*

Material	Density (kg/m^3)	Thermal conductivity λ-value (W/m.ºC)	Thermal storage capacity (Wh/kgºC)	Heat transfer time lag (250mm thickness) (hour)	Embodied Energy (MJ eq./m^3)	Global Warming Potential (kg CO_2 eq./m^3)
Rammed earth / adobe	1770-2000	1,00-1,20	0,23-0,30	10 / 9	943	38
Stone	2600-2800	2,30-3,50	0,22-0,24	5,5	1300	26
Concrete	2400	1,80	1,10	7	1450	264
Hollow bricks	1200	0,39-0,45	0,26	6	4245	357

The industrialization of construction systems and the massive use of HVAC systems homogenized the architectonic forms. In this sense, the majority of modern buildings does not show any particular concern about the relation with the surrounding environment, which is reflected in more energy consumption and consequent environmental impacts. Therefore, there is a need to learn and import climate-specific know-how from vernacular passive building technologies into our contemporary climatic responsive building practice. Thus, this study introduced Mediterranean vernacular building energy performance that end in a vernacular responsive building form.

In sum, vernacular is not only a learning example in climatic building performance but also a knowledge base of traditional building techniques; cost efficient buildings, intelligence in coping with material availability and in respecting local cultural and traditions. Vernacular architecture could contribute towards reducing waste and energy consumption through the use of passive solar design and local materials, in a process of on-going development in which building techniques are adapted for specific cases, in accordance with territory and climate [23], [24].

6. Conclusion and recommendation

It seems to be a common sense that climate is an important issue to consider in building design. But in practice, our contemporary designs are very dependent on fossil energy over the life of the building due to reliance on mechanical means to control the indoor climate. Yet, this approach has lead to many drawbacks: not only has a building's initial cost risen considerably but also running costs for periodical maintenance is quite a burden. This study indicates that, although many vernacular dwellings still exist in the Mediterranean region, it is challenging -but desired- to package vernacular architecture traditions and qualitative design knowledge to modern sustainable building designs. It is imperative that instead of relying entirely on mechanical means, the architect should learn from vernacular passive strategies and direct their efforts to reach the best possible low energy and natural climatic control for their buildings. Then mechanical and active systems can be supplementary aids, to use only when the endogenous resources are not sufficient to meet the comfort needs of occupants.

Learning from the past, the future can use the potential of existing technology and improve it in order to change the current energy paradigm. A vernacular dwelling may not fit, in many cases, with current standards of comfort, but could give some clues about strategies to mitigate the use of non-renewable energy. Through the optimization of these strategies it will be possible to satisfy the desired standards of comfort while reducing the fossil energy consumption.

The paper results proved that vernacular climatic solutions set an approach for improving contemporary building energy performance and draws recommendation for further research below: i) More intensive quantitative studies and surveys are needed to adapt vernacular passive strategies to modern applications especially after the current climate change symptoms; ii) Effective vernacular strategies should be used as guidelines for our contemporary urban planning and building design regulations; iii) Mediterranean vernacular valuable endeavor can be, with additional scientific verification and simulation tools, a design guide for contemporary energy efficient buildings in Mediterranean climate; iv) Currently there are no national reference documents for vernacular passive construction performance in both countries. A reference document could be a good start for effective contemporary application.

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References

[1] N. Cardinale, G. Rospi, and P. Stefanizzi, “Energy and microclimatic performance of Mediterranean vernacular buildings: The Sassi district of Matera and the Trulli district of Alberobello,” *Build. Environ.*, vol. 59, no. null, pp. 590–598, Jan. 2013.

[2] S. Martín, F. R. Mazarrón, and I. Cañas, "Study of thermal environment inside rural houses of Navapalos (Spain): The advantages of reuse buildings of high thermal inertia," *Constr. Build. Mater.*, vol. 24, no. 5, pp. 666–676, May 2010.

[3] J. Fernandes and J. J. Silva, "Arrefecimento passivo na arquitectura tradicional de Évora," in *Congresso Construção 2007 - 3.º Congresso Nacional*, 2007.

[4] H. Fathy, *Natural Energy and Vernacular Architecture: Principles and Examples with Reference to Hot Arid Climates*. Chicago, IL/US: The University Of Chicago Press, 1986.

[5] W. Weber and S. Yannas, *Lessons from vernacular architecture*. London: Earthscan, Routledge, 2014.

[6] A. Foruzanmehr and M. Vellinga, "Vernacular architecture: questions of comfort and practicability," *Build. Res. Inf.*, vol. 39, no. 3, pp. 274–285, Jun. 2011.

[7] AEMET and IM, Eds., *Atlas Climático Ibérico: Temperatura do Ar e Precipitação (1971-2000)/Iberian Climate Atlas: Air Temperature and Precipitation (1971/2000)*. 2011.

[8] EMA, "Annual meteorological report, Marine and weather forecast over Mediterrannean," 2013.

[9] P. Oliver, Ed., *Encyclopedia of vernacular architecture of the world. Vol. 2, Cultures and habitats*. Cambridge: Cambridge University Press, 1998.

[10] M. Turan, Ed., *Vernacular architecture: paradigms of environmental response*. Aldershot: Avebury, 1990.

[11] L. Jones and C. Nichols, *Mediterranean Landscape Design: Vernacular Contemporary*. London: Thames & Hudson, 2012.

[12] J. E. P. Fernandes and R. Mateus, "Energy efficiency principles in Portuguese vernacular architecture," in *BSA 2012: 1st International Conference on Building Sustainability Assessment1st International Conference on Building Sustainability Assessment 1st International Conference on Building Sustainability Assessment*, 2012, pp. 561–572.

[13] A. El-Sherif, "Reconciling traditions and contemporary aspirations in the Arab-Muslim city: Alexandria, Egypt.," Oxford Brookes University, 1995.

[14] H. Koch-Nielsen, *Stay Cool: A Design Guide for the Built Environment in Hot Climates*. London: Earthscan, 2002.

[15] M. Dabaieh, "A future for the past of desert vernacular architecture: testing a novel conservation model and applied methodology in the town of Balat in Egypt," Lunds Universitet, 2011.

[16] B. Givoni, *Passive Low Energy Cooling of Buildings*. New York: John Wiley & Sons, 1994.

[17] J.-P. Bourdier and T. T. Minh-Ha, *Vernacular Architecture of West Africa: A World in Dwelling*. Abingdon, Oxon: Routledge, 2011.

[18] S. Siegesmund and R. Snethlage, Eds., *Stone in Architecture: Properties, Durability*, 5th ed. Springer Berlin Heidelberg, 2014.

[19] J. F. Kennedy, Ed., *Building Without Borders: sustainable construction for the global village*. Gabriola Island, BC: New Society Publishers., 2004.

[20] C. Mäckler, Ed., *Material stone: constructions and technologies for contemporary architecture*. Basel: Birkhäuser, 2004.

[21] B. Berge, *The Ecology of Building Materials*, 2nd ed.. Oxford: Elsevier, 2009.

[22] L. Bragança and R. Mateus, *Avaliação do Ciclo de Vida dos Edifícios - Impacte Ambiental de Soluções Construtivas*. iiSBE Portugal, 2011.

[23] K. Kimura, "Vernacular technologies applied to modern architecture," *Renew. Energy*, vol. 5, no. 5–8, pp. 900–907, Aug. 1994.

[24] M. K. Singh, S. Mahapatra, and S. K. Atreya, "Solar passive features in vernacular architecture of North-East India," *Sol. Energy*, vol. 85, no. 9, pp. 2011–2022, Sep. 2011.

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IDES-EDU: Comprehensive multidisciplinary education programme to accelerate the implementation of EPBD in Europe

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Abstract: *This paper presents a new education and training programme on integrated energy design developed by fifteen European universities collaborating within the IDES-EDU project (2010-2013), funded by Intelligent Energy Europe. IDES-EDU aims to accelerate the implementation of the Energy Performance of Buildings Directive (EPBD) by proposing Master and Post Graduate education and training in multidisciplinary teams. To speed up transition from traditional, sub-optimised building projects with discipline-oriented, segregated budgets and operations, IDES-EDU developed comprehensive, multidisciplinary educational programmes targetting integrated project design at the interface of architecture and engineering. Taking into account local variations in climate, construction and pedagogical approaches, the programme facilitates gradual implementation towards full integration of energy efficiency in building education according to local capacity and legislation.*

This paper summarises the evaluation process of the first implementation of the educational material in the 15 universities, by academic staff, national industry and professional organisations, and reference students from each university. Included are expected learning outcomes, level of integration in existing curricula and alignment with theory and assessment methods. Measures for improvement as well as further dissemination to other European educational facilities are proposed. In this manner, the project will contribute to make the multiple opportunities for energy efficiency a reality.

Key words: Education, integrated energy design, multidisciplinary

About IDES-EDU

In IDES-EDU 15 European universities have jointly developed education and training programmes for MSc students and professionals in Integrated Design of the Near-Zero Energy Built Environment. IDES-EDU developed 13 education packages with 98 lectures and 22 seminars and workshops and specified intended learning outcomes in terms of knowledge, skills and general competence. The courses have been further elaborated and implemented in national consortia in which educational institutes collaborate with key stakeholders such as branch organisations of the building sector (constructors, real estate developers, architects, building research institutes, utilities, suppliers and consultants) and accrediting bodies.

IDES-EDU educational packages support students' ability to create a near-zero energy built environment that satisfies aesthetic and technical requirements. The students develop knowledge and skills needed to plan, conduct and manage a building project in co-operation with a cross-disciplinary design team and stakeholders. The project website www.ides-edu.eu provides more extensive insight in IDES-EDU monitoring, lecture material and other results, in particular Reports D6.1, D6.2 and D6.3 of which this paper forms an extended summary.

All 15 IDES-EDU universities implemented the educational material, adapted to local capacity and context. In doing so they contributed to education and training of future architects and engineers with expertise in interdisciplinary cooperation for construction practice and research. 1466 students were involved, among which 144 architects, 1203 engineers and 71 others. 210 students were involved in exchange programmes, and 755 students in internships. At least 3 IDES-EDU partners created new master programmes (Zuyd University, Warsaw University and University of Minho). IDES-EDU partners contributed to the creation of a new international master programme by iiSBE Europe (International Initiative for a Sustainable Built Environment) and have committed to contribute to this programme also after the IDES-EDU project finishes. 56 universities have expressed interest in using IDES-EDU material, potentially in cooperation with IDES-EDU partners. IDES-EDU material was disseminated through European umbrella organisations iiSBE Europe, REHVA, CECODHAS and ACE. Even higher numbers can be expected in the near future, as updating existing and creating new university programmes require several years to implement. Between the end of the project and 2020, 2000 engineers and 5000 architects are expected to have participated in the training. These figures are based on the estimation of the national REHVA members (110.000 engineers) and ACE members (530.000 architects).

Monitoring of results

This paper includes the results of a series or reviews performed to monitor the outcomes of the development and implementation of these educational packages. The review of educational material used distinct types of surveys and feedback:

- The 5-minute feedback forms with responses from the students, teachers and external reviewers provided a large quantity of feedback on detailed slides and lectures. It was hard to link the IDES-EDU common end terms to these answers point by point.
- Course evaluations also contained an evaluation of the quality of the course organisation: was the content interesting, were the classes attractively taught, how was teachers' attitude and clarity, sufficient infrastructure for the course, and so on.
- The Reference Student Group with its discussions and workshop provided a more well-rounded and context-related response to the IDES-EDU material.

The 5-minute feedback form

In addition to standard course evaluations, a low-threshold "5-minute feedback form" was developed to enable students to record reflections, thoughts and feedback during lectures – in addition to taking lecture notes, of course. It consists of 5 generic questions:

1. What is your role in the IDES-EDU project (student, teacher, external reviewer)?
2. Which lecture did you review, and what was the time and location of this lecture?
3. What, in your opinion, were the three key messages of the lecture?
4. What were the most and least useful elements?
5. Were there any unclarities or comments?

Based on tools used at NTNU Norwegian University of Science and Technology, the feedback form was adapted to fit IDES-EDU needs in cooperation with IDES-EDU partners prior to being distributed among students, teachers and professional organisations.

The 5-minute feedback form resulted in 211 answers, among which 155 from students, 33 from teachers and 23 from external professionals, and the lectures were updated accordingly. Discussions of tools, methods and procedures during lectures are highly appreciated, and mentioned frequently in “key messages” and “most useful” categories. Practical exercises with teacher support to implement tools and methods are strongly requested by respondents.

A majority of respondents emphasized the usefulness of case studies and examples to make theory more “real”, along with practical implementations such as monitoring results and processes. Some lectures were commented to have a lot of useful guidelines but lack specific examples, numbers and images which could have clarified and operationalized those guidelines; “practical important things … rather than mathematical models”. In general group work and seminars were highly appreciated: “To put the theory in practice. Advices on how to proceed. It is not as easy as it seems to aggregate all the knowledge, pick up the relevant things and apply them. It was a great practical experience.”

Some requested more discipline-specific information in the lecture material, while others reacted to information they did not find useful for their own profession. In fact this corresponds well with the scope and goal of the IDES-EDU lecture material which can be used as a cross-disciplinary introduction for architecture and engineering students alike and supported by more detailed lectures and training by the local university when required. The variety among lecture topics and the perspectives and structures used to construct the lectures, as well as the diversity in climatic and cultural context, were mentioned as useful for reminding the audience of the holistic perspective.

Several reviewers requested a combination of summary data for the whole European context and national status quo: “If this project is meant as international platform implemented on national level as well, I can imagine presenting European data with respect to various climates as quick reference and focus on national data to be able to compare, what “my” conditions are like in comparison with other EU member states.”

Course evaluations

Each university is required to perform regular course evaluations on quality of content as well as pedagogical, administrative and infrastructure frameworks. While these evaluations are not targeting IDES-EDU lectures alone, the variety of feedback provided in these documents was checked, where available (e.g., non-confidential), and relevant input categorised and integrated into the IDES-EDU framework for further development of the material.

Infrastructure, administrative services and staff resources

Most course evaluation forms include staff resources and pedagogical competency, for example related teachers' attitudes towards students, clarity of assessment criteria, punctuality and availability of the teacher. They also include questions related to availability and quality of infrastructure, design studios, group rooms and lecture halls, as well as administrative support. Evaluations also tend to include questions related to whether students' knowledge level prior to starting the course was sufficient to support efficient learning and participation.

Several course evaluations we examinsed emphasise the importance of teachers with active practice in industry, cities and research. However, this active practice also requires certain flexibility in terms of course planning, as schedules and capacity may fluctuate according to project development. This type of experience provides the students with the possibility to get engaged in research and industry projects (which makes for very attractive courses).

Pedagogical framework

Most course evaluations include questions related to the appropriateness and timing of the work load per course and per semester are evaluated; both in terms of planned activity and actual implementation. In addition students were asked how they experienced the connection between learning outcomes, learning activities and evaluation activities, availability of literature, practice- and science-based material, relevance of examination content and structure and timeliness of corresponding information, and so on.

According to the respondents, IDES-EDU course content is not always fully supporting the intended learning outcomes of the corresponding course as defined at the local university. IDES-EDU lecture material of course needs to be adapted to fit the local pedagogical framework, and combined with practical student work such as exercises, seminars, laboratory work, full-scale building and other similar activities. Workshops and other student group work suggested in IDES-EDU educational packages needs support by local teaching staff throughout the semester, in particular to promote interdisciplinary student cooperation.

Theory and assessment methods are well taken care of, and are relatively easy to evaluate. However, there is a large difference in learning threshold among students when it comes to simulation and assessment tools; some require a long time to understand a tool and therefore don't have a chance to use it properly in design projects. Generally it is found difficult to create learning activities that promote critical attitude and creative use of tools to support design projects. There are large individual differences among students as well as teachers.

IDES-EDU material with description of intended learning outcomes and identified reference literature per lecture provides a useful addition to existing courses that are based on teachers' ongoing research and projects, or their personal topic knowledge, not compendia (only recommended literature). This is also the case with practice-based exercises and design projects, as many students don't start to study or use literature as reference until just before an exam, and only then find out the theory would have been useful for their projects.

Geographical mobility

Geographic mobility and exchange of students and staff is in general highly appreciated in course evaluations. Constructive cooperation among students with widely diverse cultures, educational background and expectations and between teachers from architecture and engineering, research and practice, and various cultural backgrounds, has proven to be extremely important to achieve good learning practices. However, this requires additional capacity and activities by university partners at both ends. Due to large diversity in student mass, for example, the first weeks of a semester are mainly spent on familiarising the new students with host university routines, local and national context, and with each other. Special pedagogical training is also required to deal with student groups with diverse educational, geographical and cultural background (international and interdisciplinary).

Internationalisation of the curriculum is a second main issue. Co-operation among IDES-EDU universities has shown clear differences in pedagogical cultures and expectations, in terms of student supervision, weighting of meta-cognitive skills, and integration of design practice and research. While some of the pedagogical framework is embedded in written documents, there appears to be a lot of tacit knowledge and group behaviour that only surfaces when there is a direct conflict between practices from different universities.

Reference students and workshop

In order to get an in-depth impression of the students' experience in the IDES-EDU partner universities, a Student Reference Group was established consisting of 1-2 Reference Students at each university. Applicants were selected based on their experiences with energy in buildings related courses and interest in multidisciplinary project work, integrated energy design, and educational aspects. The Reference Group students came from a wide range of disciplines and academic traditions, and with diverse professional experiences. Most students had a background from established (generic) programs in architecture, environmental physics and building engineering on Bachelor and Master level, while some were currently taking part in relatively new MSc programs more articulated on energy in buildings related topics.

Many of the students had previously been engaged in sustainability projects and had some experience in multi-disciplinary problem solving and teamwork. During their education many had acquired experience from several institutions and university exchange programs (ERASMUS, summer school etc.), and expressed such opportunities as positive experiences that helped broaden their view, critical abilities and self-reflection. This was also mentioned as a motivation and possible outcome of being part of the work in the joint reference group.

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The Reference Group was responsible for good dialogue with IDES-EDU teachers and evaluation team throughout the semester and for encouraging fellow students to participate in the Five-Minute Feedback Form and other forms of feedback. They reviewed lecture slides and courses, based on their background, field of work, and to some extent their common interests. The students were asked to assess and discuss a range of questions, amongst others:

- Are the intended learning outcomes for the course accessible and understandable?
- Do the intended learning outcomes feel relevant and achievable?
- Do the students have the necessary prerequisite knowledge?
- How do students work on the subject? Do you have any suggestions for improvement?
- Do the lecture elements and structure support the learning process?
- Are any of the elements particularly challenging?
- Is the lecture relevant for becoming an expert on energy in buildings?
- Does the lecture meet your expectations? What can be improved?
- Do you have any comments to particular slides?

The work of the reference student group culminated in a workshop in Maastricht 23-27 June 2013, arranged in coordination with the final meeting of the IDES-EDU project at the same location and time. During the workshop the students had time to develop their own group work as well as discussion, presentation and interaction with the IDES-EDU partners.

The outcome of the Reference Group was a series of key messages and priorities as well as a joint introduction of expectations, goals and visions for courses on energy in buildings:

- Overviews of tools, methods and procedures, and their application in diverse contexts; Provide students with the tools and skills to balance specialist/holistic approaches;
- Case studies and examples; Education that provides continuous capacity to deal with the demands of construction sector and society at large – so that students gain "up-to-date" and relevant competence from building professions;
- Creating a framework for cross-disciplinary co-operation with group work and seminars; Integration to deal with increasing complexity and specialization;
- Architectural and engineering students gaining insight in "the other side": each others' professional language, educational topics and pedagogical methods, getting to know each other and discussing priorities from different professional perspectives;
- Design should be made for people;
- Including social norms and "nudging" as core elements in energy in buildings education. For example, is it easier to sell a ZEB house if "several neighbours already had purchased a similar house" rather than convincing them of technical principles?

Conclusions and outreach

IDES-EDU students, teachers and external experts have throughout the project emphasized and strengthened cooperation on integrated design of near-zero energy built environment. In addition to developing lectures and courses worth 120 ECTS, they have built a long-term co-operation model based on dialogue, reflection and interaction. The co-operation platform has not only been planned, but also implemented with regular quality insurance and updates through specific responsibilities. Above all, the importance of interdisciplinary co-operation and integrated design was highlighted by students, teachers and external professionals alike.

The main aim of the interdisciplinary courses is to help the students learn how to solve challenges related to integrated design of near-zero energy built environment. In order to achieve this co-operation among the students is a highly useful and effective didactic method. Experiences from IDES-EDU show that the students and teachers found the co-operation between architecture and engineering on the one hand, and between IDES-EDU partners on the other hand, to be very fruitful and innovative, and, above all, relevant for future practice. Therefore we recommend to continue the courses' implementation at IDES-EDU partner universities, including cooperation between architecture and engineering students, and to extend and intensify the cooperation.

Comprehensive co-operation, however, does not become successful without effort. Students, teachers and external experts have pointed out deficiencies and challenges in the current set-up. They request more extensive, in-depth co-operation between students across universities, and better organisation of the co-operation between architecture and engineering students, particularly with relation to work load, responsibility and credits. The students and teachers also request more consistent co-ordination of the different departments that allows for meaningful co-operation between the students of different learning environments. This type of co-ordination among departments requires considerable human and financial resources.

The most important step, however, was taken several years ago: to establish cooperation and initiate interdisciplinary and international education in integrated design of near-zero energy built environment. An initiative students as well as teachers and external experts appreciate considerably. What now remains to be done is an adjustment of the particular content, timing and extent of co-operation so as to continue to ensure a meaningful learning experience within the financial and administrative framework of all participating universities.

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We are extremely grateful to all students, teachers and external professionals who have gracefully dedicated their time and attention to reviewing the IDES-EDU material and filling out feedback forms, engaging in discussions and participating in the reference student workshop and exhibition. We also thank Intelligent Energy Europe programme for its financial support, Grant agreement no.IEE/09/631/SI2.558225.

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Session 25:

Which are the keys to interest owners in sustainable building?

Chairperson:

Colin, Brigitte

Consultant in Architecture, Cities and Urban Policies. UNESCO Natural Sciences Sector

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Swedish property owners'experience of added value from environmentally certified non-residential buildings

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Abstract: *The aim of this work is to show how owners of Swedish environmentally certified (EC) buildings experience added value (AV) from EC from a broad management perspective. Using a questionnaire and interview study of property owners with experience of EC we find that direct economic AV is experienced mostly in terms of reduced energy costs. Many perceive AV in terms of higher operating income, though many also perceive no noticeable difference. Results also show that EC confers notable advantages with important actors such as tenants, investors as well as internally. Analysis shows that different types of owners strategically prioritise different AVs. Commercial office owners in large metropolitan areas prioritise AV conferred by the certification itself in e.g. creating a niche market for tenants. Other types prioritise AVs in terms of better process management in development projects or property management operations in existing buildings.*

***Keywords:* Environmental certification, management, value, non-residential buildings, mixed-methods**

Introduction

Environmental certification (EC) of buildings has previously not been so widely implemented in Sweden as in other industrialised countries. Since 2012 though their application has increased dramatically. At the time of writing approximately 200 buildings have been certified and the number is growing. The most used is the domestic tool Miljöbyggnad (MB) [1], but LEED and a customised BREEAM version are also popular.

Alongside this there is a great body of research investigating the effect of EC from the perspective of the valuation professional. In a comprehensive recent literature review Warren-Myers (2012) categorises distinct fields in this research as normative theories, valuation-based research, quantitative studies and valuation methodology [2]. As Warren-Myers (2013) points out accurate valuation of sustainability aspects are important for financial reporting and motivating further investment in EC buildings [3].

On the other hand, the current body of literature pays little attention to the overall effects that EC can have when considered from the broad perspective of an owner's total operations. For efficient strategic management in any organization decision makers should manage operations from multiple perspectives, not only that of financial performance. In practice and in the research literature such a consideration finds voice in what are formally called "performance measurement systems" for organisations (see e.g. [4]). It is thus reasonable to expect that the value of any particular business strategy be assessed from all such points-of-view. Therefore to promote the wider adoption of EC in the sector it is necessary also to analyse and assess the contribution that EC can make in the non-financial perspectives of organizational performance.

Enough Swedish EC buildings now exist to be able to study how AV is experienced and potentially has been created due to the use of certification schemes. The aim of the work presented here has been to show and get practical examples on how owners of Swedish EC buildings experience AV from EC from a broad management perspective. Based on this, a characterization of ways in which EC contributes to AVs is suggested. More specific research questions applied in relation to this aim include:

- Is AV experienced as a direct financial benefit (i.e. through increased income or decreased costs related to the EC building) or as an indirect benefit (non-financial) and
- Do AVs vary depending on certain owner/building characteristics?

The study also encompasses asking respondents for an outlook concerning if AVs from EC will increase in the future and if so which ones.

Method
A multi-method approach was used. An online questionnaire survey was used to obtain specific data about pre-defined potential AVs. Semi-structured deep interviews were used to gather data specifically about an owner's own perceptions, specific strategies in applying EC and what AVs have been prioritised.

Questionnaire

In the questionnaire respondents were asked to indicate the effect EC and associated environmental measures had on direct AV related to building production and management: The building's production cost/purchase cost, (hypothetical) sale price, rental and vacancy rates, and important factors for operation costs (e.g. energy costs). The pre-defined AVs were selected based on previous studies and literature. We asked about the effect on each parameter in the "short term" and "long term" separately. Amongst questions regarding indirect AV respondents were asked to describe the degree to which EC had been advantageous in relations with tenants, investors, and internally in the organisation. Before being sent to the target group the questionnaire was pilot-tested with five members of the project's reference group (themselves owners of Swedish EC buildings).

The target group for the questionnaire was people with specific and direct experience with EC, for example building/environmental managers, for an EC building in Sweden as per the time of the survey. The questionnaire was sent to one representative for each identified non-residential building in Sweden that had been certified according to BREEAM, LEED or Miljöbyggnad. It was also sent to a small selection of people with experience of the

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application of the EU Green Building tool in Sweden. The target group therefore constituted representatives for 65 buildings. In some cases one person was asked to provide questionnaire responses for more than one building. The questionnaire was emailed to people in the identified target group. After this reminders were sent out periodically and occasionally contact was made by telephone until all potential respondents had either answered or declined to do so. Responses were received between November 2012 and April 2013.

In analysis respondents were divided according to six different building/owner characteristic categories, see Figure 1. Based on these categorisations response frequencies for each question were analysed in relation to the research aims. For brevity only the most important results for the conclusions drawn have been included in this conference article.

Interviews

Interviews were based on a template consisting mainly of open-ended questions grouped around certain themes: motive, driving forces and strategies for EC; expected and experienced AVs from EC; AV connected to specific environmental measures; communication of EC and expectations of AV from EC in the future. Each interview was carried out for as long as it seemed that it was providing new information. In general they lasted for between one and two hours each.

Potential interviewees were identified mainly from the group of questionnaire respondents. Some interviewees were identified from the project group’s personal networks. It was important to have amongst interviewees representatives for building/owner characteristic categories per those used in questionnaire analysis (see Figure 1). Interviews were mostly carried out one-on-one in person, or occasionally by telephone and were in all cases recorded in their entirety. Twelve people were interviewed. Interviewees mainly represented Swedish private companies with new office buildings in large metropolitan areas that were highly-rated according to LEED or MB. Nonetheless care was taken to ensure that at least one person representing each of the other building/owner characteristics was interviewed. In the case of BREEAM, EU Green Building and education and logistics buildings no one was interviewed because identified people representing these categories all declined. In citations below interviewees are categorized as private or public property owners and assigned numbers, i.e. private 1, 2, 3… and public 1, 2, … etc.

Summaries of each interview response were transcribed according to a matrix dissagregated as per the interview template. Questionnaire and interview results were compared and synthesized from the point-of-view of the established research questions. Considering the question of variation of AV with respect to building/owner characteristics, each interview in itself was analysed with respect to identifying features of a possible strategy guiding their application of EC. Analysis aimed to identify prioritized AVs for any given strategy and whether certain strategies are more applicable for certain building/owner characteristics.

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Results

Questionnaire responses

From the sample of 65 buildings, responses were received from 31 (including one that did not answer all questions). The distribution of respondents amongst different building/owner categories is shown in Figure 1. For most categories there is one particular characteristic that is dominant, which largely reflects the way in which EC had been applied in Swedish non-residential buildings up to that point.

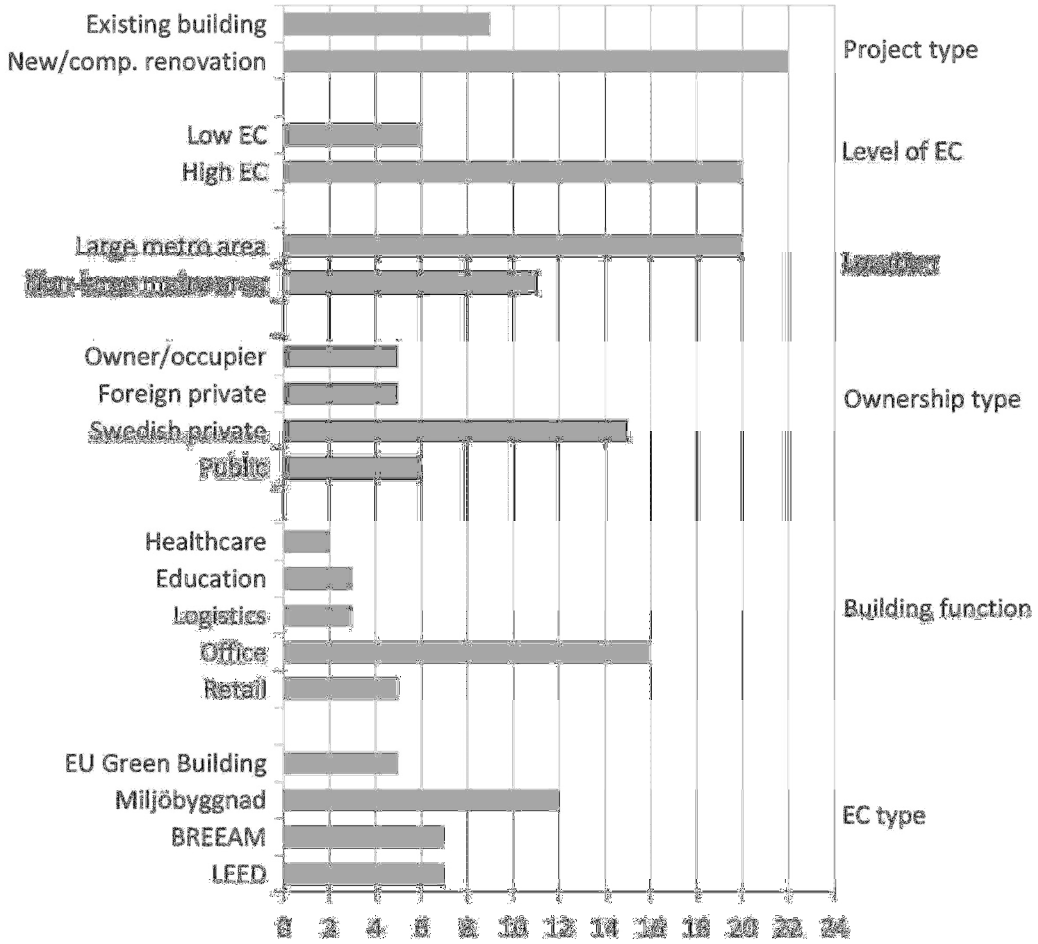

Figure 1: Disaggregation of questionnaire respondents according to different categorisation variables.

Direct added values

Table 1 summarizes questionnaire results about the effect of EC on direct economic factors. They show that reduced energy cost is the area most clearly identified for AV from EC. This was corroborated by many interview responses and is the clearest example of AV that is directly connected to specific measures for improved environmental performance. On the other hand many interviewees also noted that reduced energy costs are often achieved without EC application, e.g. with corporate energy policy.

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For most other factors affecting net operating income the table shows the majority of respondents either saw no difference or that EC conferred positive AV. For all factors more respondents saw that EC conferred AV in a long timeframe than in a short. Only with respect to tenant outfitting did a large number of respondents see increased costs due to EC, though also here a majority saw no difference.

Table 1: Summary of questionnaire results showing the experienced effect on direct economic factors of EC. Figures in parentheses are the actual number of respondents. Shaded cells indicate the answer alternative(s) for each factor/timeframe that (together) contained at least three quarters of all non-“don’t know” responses.

	Short/long timeframe	Lower	No difference	Higher	Don't know
Operating income					
Rental rate (income/m2)	s	0% (0)	76% (19)	24% (6)	5
	l	4% (1)	50% (12)	46% (11)	4
Vacancy rate	s	24% (6)	76% (19)	0% (0)	5
	l	50% (12)	42% (10)	8% (2)	5
Operating expenses					
Tennant outfitting	s	8% (2)	54% (13)	38% (9)	7
	l	13% (3)	58% (14)	29% (7)	6
Energy costs	s	86% (25)	14% (4)	0% (0)	1
	l	89% (25)	11% (3)	0% (0)	1
Operation & maintenance	s	38% (11)	59% (17)	3% (1)	2
	l	48% (14)	45% (13)	7% (2)	1
Renovation and rebuild	s	14% (4)	71% (20)	14% (4)	3
	l	36% (10)	43% (12)	21% (6)	2
Transaction aspects					
Production cost	n/a	9% (2)	13% (3)	78% (18)	3
Sale price	n/a	0% (0)	23% (6)	77% (20)	5

Considering the connection between EC and operating incomes it was pointed out (by a private owner focused on office space) that non-EC buildings may have to be discounted in order to attract tenants (as opposed to taking a premium for EC buildings). Many interviewees said that EC is an important factor in order to attract large financially-stable, desirable tenants, for whom EC may be required by the relevant environmental policy. Such responses suggest that AV in terms of rental and vacancy rates is principally achieved through the fact that the certification itself confers a “brand” to the building that is attractive to tenants.

Considering transactional aspects Table 1 shows that a large majority of respondents experienced increased production costs, and the possibility of an increased sale price. According to interviews, factors significant in influencing sale price in particular included the certification itself, but also lower operational costs (in particular low energy demand) as well as good documentation of materials.

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Indirect added values

Table 2 shows that according to questionnaire results EC is considered to be advantageous in relations with all of the actors given: tenants, investors and internally. Interview responses about advantageous relations with tenants through EC have already been presented above in relation to direct AVs. Further considering relational advantages, interviewees attribute an increased status for environmental issues internally to EC, for example:

> “Our own employees have an increased commitment. Environmental work has become more rewarding.” Public 2

> “The new work process increased status for those working with environmental issues.” Private 7

Table 2: Summary of questionnaire responses to question “To what extent is the fact that the building is environmentally certified advantageous in relation with …?” Figures in parentheses are the actual number of respondents. Percentage “don’t know” responses calculated on total number of responses. Other percentages only for non-“don’t know” responses.

	Not advantageous	Advantageous	Don't know
Tenants	7% (2)	93% (25)	10% (3)
Investors	9% (1)	91% (10)	54% (13)
Internally	4% (1)	96% (27)	7% (2)

It was clear from interviews that EC (and particulary Miljöbyggnad) was an important tool in a successful development project in particular in relation to external consultants. This came forward from both public and private owners, for example:

> “A way of quality assurance with high environmental performance. Earlier experience with e.g. consultants was that they filled in checklists about environmental choices and it was easy to take short cuts.” Public 2

The highlighted advantages internally and with external building consultants suggest that AV is obtained from EC specifically by facilitating and improving management processes and communication in the development process.

Meanwhile, all questionnaire respondents also answered that EC affected the “organisation’s credibility and brand in environmental issues” either “somewhat” or “greatly”. The significance of EC for organizational credibility and branding is further underscored by many interviewees, for example:

> “A lot of goodwill from the building. Study visits from 25 - 30 companies, local authorities and other companies in the same sector. Much media interest” Private 10

Such responses highlight the fact that the branding quality conferred by EC is important for promoting an organisation’s image with a broad range of actors as well as with tenants (see discussion under heading “direct added values” above). This further suggests that the “branding” quality conferred by the certification itself is important for AV.

Analysis

As discussed in Cole (2005) [5], EC implies changes to many diverse processes for property owners. AV can correspondingly be conferred by EC through many different mechanisms. The empirical data gathered in this study suggests that EC confers AV in three distinct but related ways. Firstly achieving the classification levels of different ECs requires that a number of different environmental measures are taken to improve the buildings’ environmental performance. AV that comes from these measures themselves we describe as “environmental measures’ AV”. As suggested above, reduced energy costs due to energy efficiency measures is an example of such an AV. Some interviewees point out that implementing EC resulted in applying measures that would not have been taken without formal EC. For example a retail developer noted that daylighting requirements for Miljöbyggnad caused the shop manager’s office to be moved to the front of the retail space giving not only daylight but also better contact with customers – a clear AV. Secondly the structure of EC, and having as a project goal a certain certification level implies changes to the process of building development and property management. AV in this area we term “process AV”. The results indicate that in principle these AVs can be obtained just by aiming for points/indicators with a relevant certification scheme even though it is also stated that the formal certification is a significant motivating factor for these process benefits. Finally full EC requires third-party certification and associates the building with the “brand” of the EC in question. AV in this area we term “certification AV”. This AV ultimately depends more on the recognisability and credibility of the EC’s brand, particularly tenants’ perceptions of it (see the discussion of tenant attraction from EC in the results section above). The certification itself does not necessarily contribute to increasing the building’s environmental performance.

Related to these three ways in which EC contributes to AV, it was easy to discern amongst interviewees four “ideal types” for specific strategies in EC implementation. Ideal type 1, we call “market strategic”. This type prioritises in particular “certification AV”, conferring it in terms of competitive advantage in attracting tenants and on the transactional market, as well as branding issues in general. This orientation is typically found in private companies (either Swedish or international) in the office market of large metropolitan areas, who prefer international tools such as LEED and BREEAM and aim for a high level of rating. Among the interviewees private 2, private 4 and private 8 in particular give expression to this orientation. Ideal type 1 is that most driven by AV in terms of increased rental rate, decreased vacancy rate and increased market value covered by much of the valuation-oriented research.

Ideal type 2 we call here “strategic development process”. The prioritized AV here comes from “process AV”, in this case an improved development process leading to higher building quality and communication of environmental issues internally. Organisations tend to be Swedish-owned (often public but possibly private). They tend to own non-office buildings, e.g. for education, healthcare, retail, and are not necessarily focused on large metropolitan

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areas. The two interviewees representing this ideal type, public 2 and private 7, had both applied and preferred Miljöbyggnad that is less known internationally but more closely related to Swedish building regulations.

Ideal type 3 we call here “strategic management process”. Here also “process AV” are prioritized, in the form of support and structure for environmental management and highlighting environmental issues in the organization. This applies to one interviewed organization. A key characteristic of this type is that it is applied for existing buildings. Other possible characteristics for such organisations are that they are not “transactionally motivated”, and that taking specific measures to achieve a high EC level is not important either. The interviewee representing this ideal type had also applied Miljöbyggnad.

Finally ideal type 4, called “non-strategic” are characterized by the fact that they did not apply EC in any intentionally strategic way, represented by interviewees public 1 and private 10. EC had been applied to their respective buildings after it was suggested by their respective contractors. After the fact, both organisations perceived AV though, notably with respect to a higher quality in the finished building and through reduced energy costs.

These ideal types are just that. All types may consider other AVs as significant in addition to those that are particularly prioritized. Interviews suggest however that the prioritized AVs for types 1, 2 and 3 affect quite decisively in particular the choice of EC scheme.

None of the ideal types prioritise “environmental measures’ AV” as we have designated it. Principle among these, as shown in Table 1 is AV from reduced energy demand. This is in principle cross-cutting for all the ideal strategy types mentioned above. On the other hand, specifically this measure may be undertaken without applying EC at all.

Conclusions

The results concerning direct AVs are coherent with the findings of the large statistical studies that have been carried out with respect to rental rate and market value (for a recent review, see [2]). These AVs are considered by questionnaire respondents to increase in the future. Interviews corroborate questionnaire results that reduced energy costs is the most clearly perceived direct AV.

Interviews suggest that AVs are not perceived so clearly in direct economic terms in other areas. In terms of the effect on operating incomes EC seems to confer AV indirectly in establishing a building in a niche market in particular for tenants and to a certain extent for investors. Other notable AVs even more difficult to express in direct monetary terms include the value reported in interviews of the use of EC for communicating environmental issues in development and management, internally and externally. For certain inteviewees the latter also seem to be very important.

Three significant ideal types for strategic EC application (and one which seems largely non-strategic) and AVs prioritized by each one have been identified. Ideal type “market strategic” prioritises “certification AV”. This compares with ideal types “strategic management process” and “strategic development process” which on the other hand prioritise “process AV”. Results suggest that the dominant ideal type orientation of different property owners depends on whether they are public or private, if they are focused on large metropolitan areas or not and if they are interested in attracting international tenants. “Environmental measures’ AV” principally constitutes added value from reduced energy cost and is cross-cutting for all ideal strategy types.

In future project work we will present full results of the study described here and consider further how strategic application of EC can be analysed from the point-of-view of performance management systems, notably the Balanced Scorecard [4].

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References

[1] Malmqvist, T., Glaumann, M., Svenfelt, A., Carlson, P.-O., Erlandsson, M., Andersson, J., et al. (2011). A Swedish environmental rating tool for buildings. Energy, 36(4): 1893-9, doi: 10.1016/j.energy.2010.08.040.

[2] Warren-Myers, G. (2012). The value of sustainability in real estate: a review from a valuation perspective. Journal of Property Investment and Finance, 30(2): 115-144, doi: 10.1108/14635781211206887.

[3] Warren-Myers, G. (2013). Is the valuer the barrier to identifying the value of sustainability? Journal of Property Investment and Finance, 31(4): 345-59, doi: 10.1108/JPIF-01-2013-0004.

[4] Kaplan, R.S., Norton, D.P. (1992). The Balanced Scorecard - Measures That Drive Performance. Harvard Business Review. 70(1):71-9, no doi.

[5] Cole R.J. (2005). Building environmental assessment methods: redefining intentions and roles. Building Research and Information. 33(5): 455-67, doi 10.1080/09613210500219063.

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How to motivate homeowners to invest in sustainable renovation?

Abstract: *It is important to induce homeowners to invest in sustainable renovation. It has been shown that homeowners are willing to renovate for many other motives than energy and cost savings. It seems therefore important to integrate homeowners' individual values in renovation decision making processes. A critical review of decision-aid methods, which are susceptible to be integrated in a process of home renovation, is presented in this paper. Methods have been primarily classified on the basis on whether or not they allow incorporating truthfully decision-makers' individual values while still improving the process effectiveness. Concepts such as constructivism, interactive and iterative process, quantitative attributes and values based on qualitative judgments, simplicity and accuracy of the methods, time use and modularity are discussed. It is concluded that multi-criteria decision making approaches using interactive and constructivist methods are the most relevant methods to use in a renovation process dealing with building nonexperts as decision-makers.*

Keywords: sustainable home renovation, multi-criteria decision making, decision-aid, homeowners' individual values.

Introduction

At the start of any home renovation project, homeowners considering carrying out a major renovation work are faced with the problem of deciding which renovation strategy they should go for. At this stage, many factors influence their decisions and homeowners, who are building nonexperts or laymen, find inspiration, support and guidance from various parties such as architects, energy consultants, building engineers, material suppliers (building experts) or friends. During that phase of the renovation project, they see and meet a myriad of barriers which can easily lead them towards the selection of a poor renovation strategy or a strategy targeting only one or two goals. Though, homeowners' preferences, wishes and behaviours are generally much more complex than that. Studies have shown that energy conservation measures as well as production of renewable energy can actually be cost-effective until a certain extent [1-3]. Some methods and tools, available on the market, allow determining the most cost-effective energy conservation measures and renewable energy production systems for a specific application [4,5]. Studies have shown that an optimised energy auditing process can considerably improve the level of energy efficiency of a renovated building and can produce reasonable estimates of energy savings [6-9]. To estimate energy savings reasonably, it is important to assess the energy consumption of buildings to a certain level of accuracy. Yet, investigations reveal significant uncertainties in the estimation of energy consumption in buildings, the most sensitive parameters being directly related to occupants' behaviours [10-12]. Although studies have shown the link between energy efficiency of buildings and behaviour of the building occupants, indoor environment quality, architecture and impact on the environment, it seems that most approaches to "energy renovation", methodologies and tools are still focusing predominantly on the resulting energy and cost savings. It appears that such a narrow focus is not justified. In the case of homes, it has been shown in reviews [6] that homeowners are willing to renovate for many other motives than energy and cost savings. In order to overcome barriers to sustainable renovation, it seems therefore important to approach the issue in a more holistic manner, to support homeowners' decision making and to integrate in the process the occupants' behaviours as well as any other factors which might directly influence them. Therefore, we have reviewed decision-aid methods with the purpose of selecting the most adapted methods to support and induce homeowners to invest in sustainable renovation.

Decision-aid methods

The presence of several independent and conflicting evaluation criteria, either qualitative or quantitative, makes the problem of selection of a sustainable renovation scenario a candidate to be solved by multi-criteria decision-making (MCDM) methods. The purpose of MCDM methods is to identify the most appropriate solution out of a set of alternatives which are characterised by multiple and possibly conflicting attributes. Interesting reviews of multi-criteria decision making methods have been done by Hwang and Yoon [13], Chen and Hwang [14], Yoon and Hwang [15], Salminen et al. [16], Andresen [17] and Hopfe [18]. Most multi-criteria approaches have advantages, disadvantages and pertinent fields of applications. Those methods vary especially according to several parameters: type of problem to resolve (structured, semi-structured, and unstructured), type of decision maker and surrounding (evaluator expertise), types and number of criteria to be taken into account, types of scales of preferences to be used, how close to the human behaviour we want the prescriptive method to be. We have sorted the approaches within two families: the decision-aid expressed by a single synthetizing criterion (SSC) and the decision-aid based on preference or human behaviour models.

Decision-aid expressed by a single synthetizing criterion (SSC)

The first type of deterministic SSC approach is the multi-attribute decision making approach (MADM). In a single synthetizing criterion or a value function approach, each of the scenarios is evaluated with respect to the criteria in order to obtain scores also called value functions. This is done by using a rating scale. Scaling factors or weights give the relative importance of each of the criteria. Once the information obtained, it is then synthesised and aggregated to give an initial overall evaluation for each scenario. The simplest deterministic method is the weighted sum method (WSM); it is generally applied in single dimensional problems. Even though green or sustainable building design is not a single dimensional problem, green building rating schemes such as LEED (LEED for Homes for new homes or green residential remodelling guidelines for existing homes), BREEAM (Code for Sustainable Home for new homes and BREEAM Domestic Refurbishment for existing homes) or DGNB (small residential buildings for new homes) have all applied the weighted sum method. Another deterministic method with simple implementation is the simple multi-attribute rating technique (SMART). It was developed by Edwards [19] based on the Multi-attribute Utility Theory (MAUT). MAUT uses utility functions, whereas SMART uses value functions. A utility function differs from a value function for the reason that it takes into account the attitude to risk. As a consequence, the value functions are much simpler than the utility functions; furthermore the evaluation process is less complex. The most widely applied SSC method is the analytical hierarchy process (AHP) or its generic form; the analytical network process (ANP), developed by Saaty [20]. In this theory, the problem is formulated in the form of a hierarchy and the decision-makers judgement in the form of pairwise comparisons. Other

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examples of SSC methods are COPRAS [21] and TOPSIS [13]. While multi-attribute decision making SSC methods can be used in an iterative and constructivist manner (i.e. constructing progressively, actively and collaboratively knowledge), and even if the weighted sum method (WSM) would be the simplest approach to be understood by nonexpert decision-makers; these methods do not incite towards an improvement of the communication around value systems and preferences. They do not use either a language in phase with the decision maker. Indeed, it has been demonstrated in multiple occasions that decision-makers tend to have difficulty in ascribing numerical values to their subjective interpretations or preferences. In addition, hesitation and knowledge acquisition are not easily introducible. SSC methods accept quantitative attributes but values based on qualitative difference judgements need to be directly quantified to relate with a synthetized function. Such a function models decisions in a very rigid and rational thinking approach. Most decision makers are very likely to be only partly rational, and be irrational in the remaining part of their actions. Furthermore, the construction of such a function is a difficult problem and requires a lot of information from the decision maker in a very short lap of time. The second approach of methods within the deterministic SSC family is the multi-objective decision making (MODM). While all the previously cited methods are multi-attribute decision making methods (MADM) and focus on the decision process itself in order to create something which is viewed as liable to help an actor taking part in a decision process either to shape, and/or to argue, and/or to transform the decision maker's preferences [22], MODM methods focus on identifying a preferred alternative from a theoretically infinite set of alternatives. The alternatives are therefore not defined explicitly, but rather implicitly by a set of constraints and indirectly by the pursuit of the objectives. However, multi-objective decision making methods (MODM) are difficultly constructivivist and computations are normally fully automatic. Interactive MODM methods exist but lack of simplicity, they are quite fastidious, time consuming and require lots of expertise knowledge. It is therefore not adapted to nonexpert decision makers. Another type is the non-deterministic SSC methods. They include game theoretical models, multi-attribute utility models (MAUT) [23] , methods based on the fuzzy and grey systems theories: fuzzy AHP [24], fuzzy TOPSIS [25], fuzzy COPRAS [26] , fuzzy multiple-criteria complex proportional evaluation [27] as well as the fuzzy linguistic methods. While in deterministic methods, change of parameter values are not considered during the decision making process (possibly after the search via a sensitivity or robustness analysis), in the non-deterministic decision making approach, the parameter values are not fixed, instead, sources of uncertainty need to be identified and parameters are treated with a risk factor. Thanks to these methods, experts can deal with uncertainties and imprecision they identify. However, most cons of deterministic SSC methods persist.

Decision-aid based on preference or human behaviour models

The outranking theory developers did not accept the fact that all alternatives are comparable. They believed that in some circumstances decision-makers do not want or are not capable of comparing all the alternatives. They refused a total compensation between criteria. Instead they used the concept of incompatibility to avoid arbitrary or fragile judgements. It is therefore why they presented the output not as a value like in the single synthetizing criterion approach but rather as an outranking graph or a partial aggregation. The partial aggregation allows the possibility of ranking, sorting and ordering the possible actions while this is not feasible with the aggregate value function approach. There are two prominent types of outranking methods [28]; ELECTRE (I to IV, IS & TRI) and PROMETHEE (I & II). An outranking relation is built in order to enable the comparison of an alternative to a pre-defined profile. This approach differs from standard classification approach because the categories considered are defined a priori and do not result from the analysis. Claude-Alain Roulet et al. [29] were inspired by ELECTRE IV [22] during the development of the ORME method. To observe how the weights modify the resulting modifications of ranking, a sensitivity analysis module embedded in the tool needs to be used. Those methods have succeeded to overcome values previously forgotten by introducing the notion of incomparability and the refusal for total compensation between criteria. Furthermore, outranking methods generally require less information from the decision maker. While most of those methods have evolved to solve recurring issues, the last versions of those methods have become very complex. This means that the decision maker may feel like having a loss of control and has most of the times no choice than trusting the decision aiding expert. The success of those methods goes therefore through the need of having a high trust between the decision maker and a highly skilled expert. Another approach is the knowledge based approach. It is applied on rules informed by past experience. An example is the application of rough set theory by Roman Slowinski [30]. Results are particularly promising when a database of past decisions is available. However, such a database and a highly skilled expert are not always available. In an ideal world, descriptive and prescriptive approaches to decision making would follow a harmonious relationship: human behaviour would lead the rules of decision-making, and decision theorists, analysts or experts would use those descriptions of behaviour and a natural and adapted language to construct or select a decision support or aid system the most adapted to the situation [31]. Based on a qualitative model of the human decision maker, Larichev hence proposed to adapt decision methods to human behaviour in ZAPROS III method [31-33]. However, this human behaviour based qualitative approach does not exactly suit the needs for the solvation of our problem. Indeed, it is a purely qualitative approach which has been developed for unstructured problems. Our problem would be more defined as a semi-structured problem with both quantitative attributes and values based on qualitative verbal difference judgements. The second issue is that the approach is quite complex and time consuming. The number of incomparable alternatives is often too high and the approach not robust enough. The last approach is the interactive and constructivist approach. It includes the MACBETH method. It is based on the additive value model but requires only qualitative judgements about differences of value. In this method, the quantitative model of values is based on qualitative verbal difference judgements. This minimizes the complexity for the decision maker. The MACBETH method has very strong mathematical foundations, is interactive, transparent and constructivist. Moreover, the method avoids the need of having the decision-maker answering very complex judgmental questions. The method complies with most of requirements sensible for homeowners: it is an iteratively constructivist, interactive and humanistic approach and still mathematically accurate; it accepts conflicting balanced criteria of importance with different types of value scales; it accepts both quantitative attributes and values based on qualitative verbal difference judgements and it allows estimating or evaluating modularly the impact of an action. However, as for most of the outranking methods, the method is quite complex and requires the participation of an expert with good knowledge about the method. This approach also includes the Hermione method. It is a qualitative multi-criteria method [34]. The particularity of Hermione is that, instead of attempting to model the decision maker preferences and then substitute his or her judgement in a model, the method focuses on structuring the problem so the decision maker can directly interact with it and aggregate in his or her mind the various influencing factors. This method can deal equally with both quantitative and qualitative aspects. The most important strength of this method is it has been developed towards avoiding this feeling of loss of control from the decision maker. The main idea is to escape a delegation of the ability to perform a global judgement or preferences to a complex mathematical model, and a need of having a high skilled and trustworthy expert. This, however, requires that the decision-maker or the decision-maker plus some aiders is or are able to structure his or their problem, as well as that they are informed enough or have enough knowledge to evaluate all the criteria. The construction of a new decision criteria structure is work intensive and must comply with a set of requirements. If the requirements are not respected, the method will not be used correctly. In practice, this can lead to confusion and to mistake results if the decision-maker or any aider does not respect coherently the method requirements. Nevertheless, the method has found a good balance between simplicity and limited loss of information. Such a method will work particularly well when there is a fair balance between quantitative and qualitative information.

Discussion

Homeowners who have been living in their home for some time are usually more aware of what make them feel satisfied or dissatisfied in the existing conditions of their home. They are often sentimental about the building because they have experienced the place in different manners. The situations of building experts making decisions and of a building expert dealing with building nonexperts as main decision makers are very different. Indeed, in the second situation, the decision making process becomes much more personal, emotional and therefore the decision makers have less tendencies of being rational in their actions and decisions.

When dealing with homeowners as decision makers, it is therefore even more important to ensure that the decision aid approach used follows a harmonious relationship with the homeowners' behaviours, values and preferences. Still, the method also needs to be accurate. The qualitative and constructivist Hermione method has shown to be interactive and humanistic, quite simple to understand, relatively accurate, accepting conflicting and balanced criteria with different types of value scales, accepting both quantitative attributes and values based on qualitative judgements and time-effective. Even though it needs the presence of a building expert (or at least of an advanced tool interface), we recommend giving a priority of use to the Hermione method. If it does not lead to the distinction of a most favourable renovation scenario within the alternatives which fulfil the objectives, we suggest that the expert presents to acceptable alternatives to other experts participating to the building renovation project and discuss the issue. The use of the MACBETH method could be another option. The paper has presented decision-aid methods which could allow a human-based customization and a possible integration of nonexpert decision-makers in a sustainable home renovation process. Yet, these methods need to be adapted and combined with properly selected tools in order to be able to deal with building nonexperts as main decision makers.

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References

[1] Kragh, J., Rose, J. (2011). Energy renovation of single-family houses in Denmark utilising long-term financing based on equity. Applied Energy, 88(6), 2245-2253.

[2] Amstalden, R. W., et al. (2007). Economic potential of energy-efficient retrofitting in the swiss residential building sector: The effects of policy instruments and energy price expectations. Energy Policy, 35(3), 1819-1829. doi:10.1016/j.enpol.2006.05.018.

[3] Martinaitis, V., et al. (2004). Criterion to evaluate the "twofold benefit" of the renovation of buildings and their elements. Energy and Buildings, 36(1), 3-8. doi:10.1016/S0378-7788(03)00054-9.

[4] Christensen, C., et al. (2006). BEopt™ software for building energy optimization: Features and capabilities. USD O.Energy.Golden, Colorado, National Renewable Energy Laboratory.

[5] Intelligent Energy Europe. (2008). E-RETROFIT-KIT, tool-kit for "passive house retrofit". Retrieved, 2011, from http://www.energieinstitut.at/retrofit/Dateien/Startseite/E-RETROFIT-Popular.pdf.

[6] Gram-Hanssen, K., Christensen, T. H. (2011). Improving the energy labelling scheme. (No. SBi 2011:23).Statens Byggeforskningsinstitut, SBI.

[7] Laustsen, J. (2000). Energy labelling of buildings in denmark. Danish Energy Agency, 1-20.

[8] SQUARE. (2010). A system for quality assurance when retrofitting existing buildings to energy efficient buildings – WP6 – national pilot project in Finland – final report.

[9] Wierzba, A. L., et al. (2011). A study to optimize the potential impact of residential building energy audits. Energy Efficiency, 4(4), 587-597. doi:10.1007/s12053-011-9106-x.

[10] Brohus, H., et al. (2010). Influence of occupants' behaviour on the energy consumption of domestic buildings. Antalya: Clima 2010 : 10th Rehva World Congress.

[11] Koiv, T., et al. (2010). Indoor climate and energy consumption in residential buildings in estonian climatic conditions. WSEAS Transactions on Environment and Development, 6(4), 247-256.

[12] Larsen, T. S., et al. (2010). Occupants influence on the energy consumption of Danish domestic buildings. ().Aalborg University. Department of Civil Engineering.

[13] Hwang, C. L., Yoon, K. (1981). Multiple attribute decision making: Methods and applications: A state-of-the-art survey Springer-Verlag New York.

[14] Chen, S. J. J., et al. (1992). Fuzzy multiple attribute decision making: Methods and applications Springer-Verlag New York, Inc.

[15] Yoon, K., Hwang, C. L. (1995). Multiple attribute decision making: An introduction Sage Publications Thousand Oaks, CA.

[16] Salminen, P., et al. (1998). Comparing multicriteria methods in the context of environmental problems. European Journal of Operational Research, 104(3), 485-496.

[17] Andresen, I. (2000). A multi-criteria decision-making method for solar building design. Norwegian University of Science and Technology, Faculty of Architecture, Planning and Fine Arts, Department of Building Technology.

[18] Hopfe, C. J. (2009). Uncertainty and sensitivity analysis in building performance simulation for decision support and design optimization. Technische Universiteit Eindhoven.

[19] Edwards, W. (1971). Social utilities. Engineering Economist, Summer Symposium Series, 6 119-129.

[20] Saaty, T. L. (1990). How to make a decision: The analytic hierarchy process. European Journal of Operational Research, 48(1), 9-26.

[21] Zavadskas, E. K., et al. (1994). The new method of multicriteria complex proportional assessment of projects. Technological and Economic Development of Economy, 1(3), 131-139.

[22] Roy, B., Bouyssou, D. (Eds.). (1993). Aide multicritère à la décision: Méthodes et cas.

[23] Keeney, R. L., et al. (1979). Decisions with multiple objectives: Preferences and value trade-offs. Systems, Man and Cybernetics, IEEE Transactions On, 9(7), 403-403.

[24] Van Laarhoven, P., Pedrycz, W. (1983). A fuzzy extension of saaty's priority theory. Fuzzy Sets and Systems, 11(1), 199-227.

[25] Wang, Y. M., Elhag, T. (2006). Fuzzy TOPSIS method based on alpha level sets with an application to bridge risk assessment. Expert Systems with Applications, 31(2), 309-319.

[26] Zavadskas, E. K., et al. (2009). Multi-attribute decision-making model by applying grey numbers. Informatica, 20(2), 305-320.

[27] Zavadskas, E. K., Antucheviciene, J. (2007). Multiple criteria evaluation of rural building's regeneration alternatives. Building and Environment, 42(1), 436-451.

[28] Belton, V. (1990). Multiple criteria decision analysis–practically the only way to choose. (No. 1990).Operational Research Society Birmingham.

[29] Roulet, C., et al. (2002). ORME: A multicriteria rating methodology for buildings. Building and Environment, 37(6), 579-586. doi:10.1016/S0360-1323(02)00005-7.

[30] Slowinski, R. (1992). A generalization of the indiscernibility relation for rough set analysis of quantitative information. Decisions in Economics and Finance, 15(1), 65-78.

[31] Larichev, O. (1999). Multicriteria decision making: Advances in MCDM models, algorithms, theory and applications. In T. Gal, T. J. Stewart & T. Hanne (Eds.), (pp. 5-1-5-24) Springer.

[32] Larichev, O. (1992). Cognitive validity in design of decision-aiding techniques. Journal of Multi-Criteria Decision Analysis, 1(3), 127-138.

[33] Larichev, O., & Moshkovich, H. M. (1997). Verbal decision analysis for unstructured problems Kluwer Academic Publishers Boston.

[34] Flourentzou, F., et al. (2003). Hermione, une nouvelle méthode d'agrégation qualitative basée sur des règles. 58èmes Journées du groupe de travail Européen d'aide multicritère à la décision, Moscow.

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Integration of sustainability aspects into property valuation practice

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Abstract: *There is now widespread recognition that buildings which are not resource efficient and which are not equipped to flex to changing occupier needs will not be future proofed in market value terms. Therefore, this paper addresses the current state of integrating sustainability aspects into both, valuation guidance/standards and professional practice. Based on a survey among members of the Royal Institution of Chartered Surveyors – RICS, the largest organisation for property professionals worldwide – this paper discusses the extent to which valuers are aware of sustainability-related valuation guidance/standards and the extent to which valuers have actually amended their practices in response to such guidance. The paper also identifies theoretical problems and practical barriers hindering an integration of sustainability aspects into valuation practice. Finally, the paper comments on latest amendments to valuation standards enforced by RICS and on the far-reaching implications these amendments entail for valuers' clients – i.e. for the entire real estate industry.*

*Property valuation, real estate appraisal, sustainability, sustainable development***.**

Background and introduction

This paper presents and discusses selected results of an international survey among members of the Royal Institution of Chartered Surveyors (RICS) on the integration of sustainability aspects into property valuation practice. In order to understand the background and the results of the survey, it is necessary to give a brief overview on the rationale for integrating sustainability aspects into valuation as well as on basic valuation concepts.[1] Property valuation provides a key information base for almost all decisions along the life cycle of building (e.g. transaction, financing, development, modernisation or demolition) and ensures the functionality of real estate markets by creating transparency regarding prices and qualities. The theory, practice and the market impact of property valuation can be explained (in a very brief and highly simplified manner) as follows:

1. *Theory of valuation:* In essence, any valuation method is based on comparison. Therefore, the fabric with which valuers work consists of comparable transactions. And the basic tool of valuation is market and transaction analysis. Usually, this consists of (1) the collection of (transaction and rental) prices and data on quality attributes of properties and their location,

[1] The focus of this paper as well as of the survey discussed is on commercial (i.e. rent/income generating) properties. In addition, the explanations in the paper mostly relate to valuations based on market value. Another important basis of valuation is investment value, but a detailed discussion is beyond the scope of this paper. For full definitions of market and investment value and related explanations see: [1]. For a further discussion of the possibilities to integrate sustainablity aspects in valuation depending on the underlying basis of valuation – i.e. market value or investment value – see: [2].

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and (2) the analysis of the relationship between quality attributes and prices (or derived valuation input parameters) in multiple regression models and/or by using other analytical tools and approaches.

2. *Practice of valuation:* The main task of property valuation is the estimation of a hypothetical market price (i.e. market value as defined in [1]). Depending on the type of the subject property (e.g. rented or owner-occupied) different valuation approaches and valuation input parameters are used for this estimation. In any case, the subject property (valuation object) needs to be compared with observed transactions (sample) regarding those quality attributes which significantly impact on prices, rents or other valuation input parameters. The critical task of the valuer is to set/specify each valuation input parameter so that it reflects the particularities of the subject property relative to the typical market range.
3. *Market impact of valuation:* The valuation result – i.e. the estimated price – is an input parameter for the decision-calculus of market players (e.g. developers, investors) and therefore impacts the decision whether a development, a modernisation or a transaction is perceived profitable and hence carried out or not.

If information/data regarding certain quality attributes of buildings are not collected and analysed, a probable impact on the transaction and/or rental prices may not be reflected in the valuation and may therefore also not play a role within market players' decision-making. This certainly applies for a subset of quality/performance attributes related to the sustainability credentials of buildings. Several problems emerge from this:

1. *Theoretical:* Without prior quantitative analysis it cannot be argued that a quality/performance attribute has no significant impact on transaction and/or rental prices because this would mean *assuming something which can only be the result of the analysis*. The significance/relevance of a particular quality attribute without prior quantitative analysis of prices can only be justified by means of surveys among buyers and sellers (or tenants and landlords). Otherwise an exclusion or inclusion of a quality/performance attribute within a valuation and/or analytical model can only be justified by (1) the qualitative judgement (i.e. subjective opinion) of the valuer/analyst, or (2) the lack of available data, or (3) the lack of resources for data collection.
2. *Practical:* Whether empirical evidence exists or not, it remains the responsibility of the valuation professional to take into account all those quality attributes in the valuation which he/she considers being price-relevant within the given market. But if there is no empirical evidence (there may only be anecdotal evidence, a strong theoretical case, or evidence from other property markets), the integration or the exclusion has to be based on the valuation professional's qualitative judgement.[2]
3. *Market-related:* If sustainability aspects are not reflected in valuations and the associated data-collection routines of the valuation community, the impact of sustainability aspects on transaction/rental prices cannot be adequately analysed, the identification of market

[2] Among the most difficult and most important (but sometimes underrated) tasks in writing valuation reports is to identify and justify in a transparent and understandable manner the elements of qualitative judgment (subjective opinion) which have led to a particular value estimate.

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barriers for sustainable buildings is impeded, and, at least, policy recommendations for the establishment of more sustainable real estate markets cannot be provided.

Key barriers for an integration of sustainability aspects into valuation practice are: (1) a lack of sustainability-related data and/or resources to collect data, (2) a perception of valuation professionals and analysts (at least within some countries and/or among some professional groups) that collecting and taking into account sustainability-related data can be avoided until there is “enough” empirical evidence available – hence creating a stalemate situation, and (3) the scarce of guidance on how to integrate sustainability aspects into valuation practice against the backdrop of a lack of empirical evidence/analysis. Nonetheless, the implement-tation of sustainable development principles within real estate markets requires the integration of sustainability aspects into the theory and practise of property valuation (see also: [2]).

Survey among valuation professionals

In 2009, RICS published a global Valuation Information Paper (VIP13) on sustainability and commercial property valuation [3]. At that time, this was the first attempt of a valuation standard setting body to advice professionals on how to cope with the issue of sustainability in commercial valuation practice. However, as the name of the publication implies, the document was of *informative character* only; i.e. in no way binding for RICS members. Therefore, efforts were undertake by the RICS Valuation and Sustainability Group to “upgrade” the information paper into a global Guidance Note – according to RICS terminlogoy a Guidance Note contains *recommended good practice* and is quasi-mandatory for RICS members. Within the scope of this work, an online-survey was undertaken by the authors of this paper (see table 1 for further information) in order to evaluate the uptake of VIP13 among RICS members. Additional research interests of the survey were focussed on the following: (1) type, availability, collection routines and useage of sustainability-related information/data within valuation assignments, (2) types of clients requesting sustainability-related information/data as part of a valuation, (3) perceived impact of sustainability credentials on market value and investment value, and (4) choice of valuation input parameters in order to reflect sustainability aspects within value estimates.

Table 1: Survey overview

Regions	Germany	Switzerland	UK and other regions
Duration	20/08/2012 until 05/09/2012	03/09/2012 until 18/09/2012	01/07/12 until 01/09/12
Sample	Direct e-mail to ca. 3000 RICS members	Direct e-mail to ca. 465 RICS members	Announcement on RICS website only
Responses	124 (4,1 %)	43 (9,2 %)	138 (-)

Overall, the uptake of VIP13 across the countries represented in the survey was very well; in Switzerland almost 40% of respondents stated that they either always or occasionaly refer to the provisions of VIP13 when undertaking valuations; compared to 35% in the UK and above 50% in Germany. Figure 1 shows which sustainability aspects are actually taken into account by professionals within valuation assignments due to their perceived impact on market value. Note that the percentage figures indicate the response frequency and not strength or magnitude of

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impact.

Figure 1: Sustainability aspects and valuers' perception regarding an impact on market value

These findings give credence to the assertion that sustainability issues are being increasingly embedded into the canon of value influencing factors and are actually considered in valuation assignments.

Figure 2: Sustainability aspects and data un-availabilty

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Figure 2 indicates for which sustainability aspects valuation professionals are unable to collect information/data. Aparently, the situation regarding data (un-)availability is very heterogenous across countries. In addition, it is very interesting to see that even for classical attributes (which are nowadays termed sustainability issue) such as adaptability and flexibility often information/data is not available as well. In the future, such problems could be solved by the increased application of building files / building documentation.

Figure 3: Sustainability-related data availability, collection routines and useage in Germany.

Figure 3 gives an overview on sustainability-related data collection routines and actual data useage in Germany (similar results have been obtained for the other countries). The figure hightlights that even when information/data on relevant attributes are available and collected, they are not always used for the analysis / valuation. This might indicate that some valuers are already following the recommendation of RICS to collect data on many sustainability features, even if they do not currently have an impact on value. So the data is collected but does not yet feed into the valuation but can be used for analytical purposes at a later stage. This was a fairly surprising result.

Figure 4: Types of clients most likely instruct integration of sustainable attributes in valuation.

Figure 4 indicates which clients typically request the inclusion of sustainability issues within a valuation exercise. Apparently investors and owner occupiers take a leading role here but with significant differences between countries. The highest demand on the client side can be

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observed in Switzerland followed by Germany. Finally, figure 5 explains for selected sustainability-related aspects which valuation input parameters are being used in order to factor in sustainability issues into the actual valuation when estimating market value.

Figure 5: Factoring in sustainability issues into estimates of market value

It is interesting to see that considerable differences exist between valuation practices in difference countries and that certain aspects feed into a valuation through three different input parameters: rental bid, rental growth and yield. This may be due to several reasons. In any case, this practice increases the risk of double/triple counting and also makes it very difficult for valuation users to understand and trace the valuation professional's thought process.

These and other findings from this survey have been used by the RICS Valuation and Sustainability Group in order to shape the Guidance Note on Sustainability and Commercial Property Valuation [4] which was published in October 2013. Together with the 2014 edition of the RICS Valuation Standards (commonly referred to as the Red Book, see [5]), the Guidance Note will not only challenge valuation professionals but also their clients.

Challenges for valuation professionals and their clients

According to the latest RICS valuation guidance/standards, valuation practitioners now *must* (1) explicitly recognize the importance of sustainability considerations within valuation assignments and (2) extend their data collection and inspection routines accordingly. The RICS Red Book acknowledges *sustainability as a potential value driver and risk factor.* Therefore, valuers are advised to "[…] assess the extent to which the subject property currently meets sustainability criteria and arrive at an informed view on the likelihood of these impacting on value, i.e. how a well-informed purchaser would take account of them in making a decision as to offer price, […].” [5, p.59-60]

In addition, the Guidance Note (which accompanies the more generic requirements contained within the Red Book) contains a checklist of data and other information factors “that valuers should consider collecting where feasible, whether or not there is direct evidence that these currently impact on value.” [4, p.18]. It argues that “by so doing valuers will be contributing to the systematic improvement in data that will help ensure that, as markets become sensitised to sustainability issues, appropriate analysis can be undertaken to support future estimates of value.” [4, p.18]

But valuation guidance also places pressure and new demands on clients. The RICS Guidance Note encourages valuers to request property performance information from their clients: “In undertaking their investigations, the valuer should also ask their clients to provide data (e.g. on energy performance). If clients are unable (or unwilling) to provide data, then this should be treated as a potential additional risk factor.” [4, p.9]

An important implication arises for clients. Whenever a client (owner organisation) needs a property valuation performed to RICS standards (e.g. for their accounts), there will be a demand for extended information. This entails the establishment of a properly managed internal information flow and an organised information system *since the provision of sustainability-related data/information will avoid additional risk premiums in the valuation process.*

These recent alterations to the RICS’ Red Book and the accompanying Guidance Note are by far the strongest endorsement of sustainability as a potential value driver and risk factor contained in any professional valuation standard, nationally or globally. It is clear that this will create a demand for education and training of professionals. But since this alteration is recent, it is too early to tell how valuation professionals will cope with these new standards and their far-reaching consequences for valuation practice.

References

[1] IVSC (2011). *International Valuation Standards 2011*. International Valuation Standards Council, London.

[2] Lorenz, D. and Lützkendorf, T. (2011). *Sustainability and Property Valuation – Systematisation of existing approaches and recommendations for future action*. Journal of Property Investment & Finance, Vol. 29, No. 6, pp. 644–676.

[3] RICS (2009). *Valuation Information Paper No. 13 – Sustainability and Commercial Property Valuation*. Royal Institution of Chartered Surveyors, London.

[4] RICS (2013). *Sustainability and commercial property valuation*. RICS guidance note, Royal Institution of Chartered Surveyors, London.

[5] RICS (2014). *RICS Valuation – Professional Standards*. Royal Institution of Chartered Surveyors, London.

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Shifting the ownership paradigm in the built environment

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Abstract: *Net positive design often involves sharing or exchange of some form of resource – energy, information, water, etc. – beyond the single building scale. In general understandings common in many Western contexts, ownership is often defined as the sum of total rights held by various persons or groups of persons over things. This definition, however, may limit the potential to advance net positive design in building design frameworks. Shifting from a privately oriented to a relational ownership paradigm could potentially influence the future of building design. This paper queries the potential shift, also considering what changes may occur in spatial and temporal boundaries of a building project when shifting paradigms.*

Keywords: Net positive, resource exchange, ownership, environmental building design,

1 INTRODUCTION

The future of building design may need to go beyond the efforts of green or 'eco-efficient' design in order to overturn the negative environmental effects of human presence on earth [1]. As an approach to net positive building design, regenerative design and development promotes a 'coevolutionary, partnered relationship between socialcultural and ecological systems that builds, rather than diminishes, social and natural capitals' [2]. Understanding the world as a set of complex, interactive, interdependent, and evolving social-ecological systems (SES) implies resource exchange between systems, and with it a rethinking of the notion of ownership.

There are many who question what role contemporary concepts of private ownership have in today's world – with clear implications for social inequality, economic instability and ecological unsustainability [3]. Many issues demand attention when questioning the role of contemporary concepts of private property: what set of cultural values, practices and concepts define a private ownership paradigm? What limitations do current private property-regimes impose on building design, the built environment or other broader sustainability goals? What are the dynamics of resource flow and capital accumulation in more socially-oriented ownership models? How do stakeholder roles, rights and liabilities shift in collective ownership models?

The purpose of the paper is, therefore, to explore broader conceptualizations about ownership that regard it as an evolving dynamic system of social-ecological relations around property – instead of a static structure of rights –, and examine their potential to facilitate net positive design achieve regenerative sustainability. A key premise of this paper is that a shift from private to relational ownership paradigms can potentially facilitate the concept of net positive building design.

2 DEFINING OWNERSHIP

An ownership paradigm can be defined as the set of practices, values and concepts held by a particular community in regards to property and property relations. Set within an ownership paradigm, a property-regime can be defined as ‘the structure of rights and responsibilities characterizing the relationships between individuals or groups of individuals with respect to things’ [4], and includes both the structure of rights and duties and the governance system or rules under which those rights and duties operate.

Concepts regarding ownership reflect how people see themselves both as individuals and part of a community, their ‘perceptions of interdependence’, and what they expect about the control they exert over a particular place or object [5]. Although common in Western usage, understandings about ownership as ‘the sum of total rights which various persons or groups of persons have over things’ [6] seem narrow and innefective for a broader understanding of how we relate to each other and our physical environment.

A more contemporary anthropological conception of ownership and appropriation regards them as processes of social interaction rather than attributes awarded to owned objects [7]. In describing property relations, Strang and Busse [8] suggest that ‘ownership is a culturally and historically specific system of symbolic communication through which people act and through which they negotiate social and political relations’, placing both social and ecological embeddedness at the core understanding of the concept of ownership.

3 FROM A PRIVATE TO A RELATIONAL OWNERSHIP PARADIGM

With increasing neoliberalization across a range of contexts and governance realms, there has been unparalleled push towards a focus on exclusive private property rights [9]. And even as free-market capitalism has proven to be inadequate for a range of issues from poverty and hunger, financial crisis, to climate change and overall system degradation, private property-regimes still sit at the core of contemporary neoliberal agendas [10].

In a private ownership paradigm, the value given to property is almost entirely determined by individual economic wealth accumulation – a primary function of free markets and private property-regimes. In this sense, any ownership paradigm that fosters the idea of unrestricted material growth as the fundamental source of economic stability and human well-being, is incompatible with the natural world in which societies live and depend on and inconsistent with any sustainability logic, and therefore, destined to collapse [11]. While some of these notions may appear over-stated, it is clear that there are fundamental tensions and inconsistencies between private property-regimes, free-market orientation, and sustainability principles and goals.

A relational ownership paradigm requires a shift beyond standard property-regimes based on an understanding of ownership as a ‘static bundle of rights’. McCay [12] separates property regimes into two parts: type of property-rights of things and their governance structure. Layering governance structures together and coupling them with property-right types allows for a much richer matrix of ownership model possibilities that can adapt to changing temporal and spatial conditions of place. Ownership models can then be understood within an

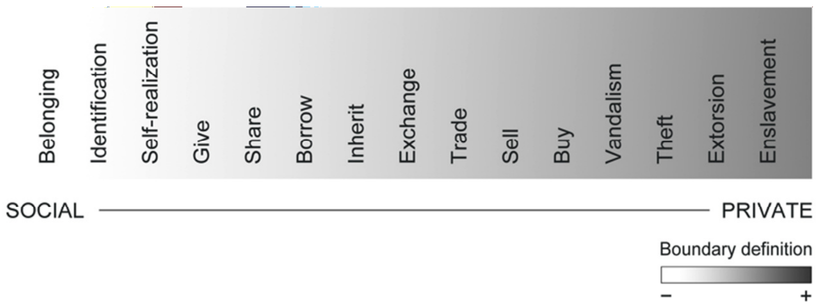

Figure 1. Boundary definition related to notions of ownership within a private-social ownership spectrum.

ownership spectrum with privately oriented models on one end, and socially oriented models on the other. A progression towards the social end of the spectrum potentially holds more collaborative, cooperative, and collective means of human organization around property – including notions such as belonging, identification, self-realization, giving, sharing or borrowing [13]. This progression implies a shift towards a less bounded and dynamic understanding of the concept of ownership where social and ecological relations, and not free-market and individualistic values, are key to informing ownership concepts (Figure 1).

Considering the spectrum above, this research advances that a shift towards a relational ownership paradigm is facilitated by:

1. A shift from principles based on misleading ideas of separability, autonomy and control to those centered on ideas of collaboration, cooperation, and shared responsibility;
2. An understanding of ownership as social and ecological relations rather than a set of abstract norms with no social function;
3. Dynamic, flexible, evolving social structures and institutions that foster the development of policies and regulations that support social ownership models;
4. A re-alignment of current market-type societal values [14] to those centered on ideas of collaboration, cooperation, and shared responsibility; and,
5. A shift from a 'mechanistic' to an 'ecological' worldview that regards the world, as a network of multiple complex SES interconnected and interdependent at different temporal and spatial scales [15].

5 CONSEQUENCES FOR BUILDING DESIGN

Boundary Definition

In a private ownership paradigm, property-regimes conceptualize a building project as the commodification of space, and define its boundaries in reference to institutional legal codes

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and regulations. Spatially, a building project is generally limited to its property lines, defining buildings as an isolated and independent closed system. Temporally, current building design practice generally covers from conception until commissioning or occupation. Such conceptualizations restrict a building's capacity to connect with neighboring building systems and limit the potential for resource exchange. Temporarily, this understanding ignores crucial long-term feedbacks that may not be apparent in such short timespan. Furthermore, current green building assessment tools, such as LEED and Living Building Challenge, also operate within a private ownership paradigm. They are rooted in a 'mechanistic' worldview, informed by principles of separability, control and self-sufficiency, and they focus mainly on increasing energy and material efficiency and minimizing the negative environmental effects of buildings [16].

Aligned with a relational ownership paradigm, regenerative sustainability conceptualizes a building in terms of its relation to the larger SES it is 'nested' in [17], not in isolation. Expanding the spatial boundaries of building projects, opens channels for the potential exchange, sharing, or trading of resources, and allows buildings to work collaboratively to increase the regenerative human and natural performance of the whole. Such is the case of the Center for Interactive Research on Sustainability (CIRS) at the University of British Columbia's Vancouver Campus. Without the standard limitations imposed by private property on neighboring buildings with different owners, the CIRS building is able to capture and use waste heat from the neighboring Earth and Ocean Sciences (EOS) building to partially supply its heating demands, only to later return excess back to EOS, reducing energy consumption of the greater system [18]. Similarly, a network of buildings might – with multiple stakeholder and institutional support at various levels – collectively engage in the construction of a local wastewater treatment plant to provide the immediate system with treated water. This collective action would not only reduce their dependence on city water, but it could potentially eliminate storm water runoff, thus reducing city storm and water infrastructure. By recognizing a building's inherent connections to other SES, regenerative design and development works to 'generate a cascade of capacity development up and down system scales' [19].

Connectivity

A regenerative discourse embraces values of interconnectedness, interdependency and whole/living systems [20]. For this, it is useful to think of all complex systems, including buildings, as purposeful network or system that fosters the idea of collaborative actions to work together towards a common environmental goal. Increasing connectivity in a system often means the various subsystems in a network can more efficiently use, share and combine their ideas, resources, services, and infrastructure. Such is the case of Kalundborg Symbiosis in Denmark, a public and private network of building systems 'where the by-product residual product of one enterprise is used as as a resource by another enterprise, in a closed cycle […] resulting in mutual economic and environmental benefits" [21]. Creating a connected network where resources can be exchanged, traded, or shared can also help uncover hidden resource exchange opportunities. A building might be individually net positive in terms of heat, but if that resource is not used within a greater resource network, the resource is considered waste. Herein, the concept of collective effort is implicit in the development of regenerative SES.

Resource flows and capital accumulation

Resource flows –i.e., energy, material, information, etc. – within and across building projects are also defined by the concept of ownership. Moreover, the manner in which social structures conceptualize ownership determines the potential of building systems to build, store and transform financial, sociocultural, or intellectual capital.

In private property-regimes, the ‘incorporeal rights’ of property – that is, the rights to sale, trade, transfer, share, or dispose of – that determine the allocation and flow of resources within a system often disregarding any form of social function [22]. The codes and regulations that were developed mainly to guarantee exclusive property rights of buildings restrict resource exchange between neighboring buildings. Multiple stakeholder liabilities and poor institutional support also contribute to discourage collective efforts towards greater environmental goals.

When transitioning towards a relational ownership paradigm, the way we understand the concept of a net positive building also becomes increasingly important. It is highly improbable that an individual building can achieve complete resource net positive status, and if it does, its physical, financial, and social conditions might prove it impossible to replicate elsewhere. The regenerative discourse recognizes that many important factors that determine the potential of a project to become net positive do not always reside within scale of an individual building, and are only achievable by expanding the temporal and spatial scales to include the ‘larger [social-ecological] systems in which a building is nested’ [23]. The importance of a building then resides in its role within resorce flows and accumulation at greater SES scales. A building project might be individually ‘water positive’ and not ‘energy net positive’, but it might contribute to the overall energy effectiveness of larger SES.

Partnerships are means of social organization around property that focus on the integration and sharing of sociocultural, intellectual, financial and natural capital for a common benefit. By sharing resources and technologies, building system’s can engage in complex collective tasks and pursue ventures previously unimaginable by individual buildings. As part of their Climate Action Plan, the University of British Columbia in partnership with Nexterra Systems Corporation, worked together to develop the Bioenergy Research & Demonstration Facility, a community-scale biomass-fueled energy plant that is expected to provide heat and electricity to the Vancouver Campus [24]. This project would be financially unfeasible at an individual building scale and certainly technologically impossible without a partnership structure that allows the sharing and exchange of information resources.

Institutional support and stakeholder engagement

Institutional support will play a fundamental role in enabling a shift away from current dominant private property-regimes. The role of government institutions is ‘instrumental in the design, implementation, and enforcement of resource regulations’ [25]. It is important to develop new policies with clear collective goals that enable and foster cooperative relationships at scales larger than a single building, and where resource exchange between legal boundaries is possible, well regulated, and encouraged [26]. And this must be accomplished while avoiding regulatory schemes that result in unwanted negative feedbacks such as unfair resource distribution, ecosystem degradation and economic instability.

A paradigm shift will not be possible without the effective engagement of different stakeholders, governance institutions and policy developers at multiple scales [27]. Understanding stakeholder needs, priorities, and limitations is central to an adequate transition towards more collaborative means of social organization. Effective community participation in decision-making processes is fundamental, especially in the later stages of a building project in order to ensure an ongoing regenerative capacity. It requires that designers, owners, developers and building inhabitants work together in a synergistic manner in order to achieve the goals set by social ownership models. Unless these recommendations are implemented, regenerative development might be restricted to seldom and isolated cases.

6 CONCLUSIONS

The development of net positive building systems can potentially be advanced by a shift towards a relational ownership paradigm where ownership is understood as an evolving dynamic system of social-ecological relations around property – instead of a static bundle of rights over things.

Aligned with a relational ownership paradigm, regenerative design and development recognizes the social and ecological embeddedness in the act of building, and asserts that the development of net positive buildings may be advanced through: (1) a broadening of the spatial and temporal boundaries of a building project to include neighboring building systems; (2) increased connectivity through the understanding of the built environment as a complex purposeful network or system where resources can be exchanged, traded or collectively generated; and (3) by engaging in collective efforts such as parnerships where resource flows create greater human and natural capital at lower operational costs. This will require rethinking the role of stakeholder, increased community participation, and the development of an institutional framework of supporting policies and regulation.

Removing regulatory obstacles that private property-regimes impose on building boundaries would have important consequences in terms of legal liabilities not covered in this paper. Understanding these and other institutional restrictions that hinder the transition towards a relational ownership paradigm in many Western societies holds important intellectual value, and represents an area for further research.

Even if collaborative means of ownership are not a final solution to a broader sustainability discussion within net positive building design, their study holds important intellectual value and they serve as powerful explorations towards a broader conceptualization of ownership as means of shaping human and natural relations. And most importantly, the alternative socially-

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oriented values that underlie a relational ownership paradigm may serve as an important feedback into a much-needed shift towards a truly sustainable building practice.

REFERENCES

1. Pedersen Zari, M. 2012. Ecosystem services analysis for the design of regenerative built environments. *Building Research & Information* 40(1): 54-64; Mang, P. & Reed, B. 2012. Designing from place: a regenerative framework and methodology. *Building Research & Information* 40(1): 23-38.
2. Cole, R.J. 2012. Regenerative design and development: current theory and practice. *Building Research & Information* 40(1): 1-6; Cole, R.J. & Oliver, A. 2012. The next regeneration. *The Canadian Architect* 57(7): 29-30.
3. Heynen, N., MaCarthy, J., Prudham, S. & Robbins, P. (eds) 2007. *Neoliberal environments: false promises and unnatural consequences.* New York: Routledge
4. Bromley, D.W. 1991. *Environment and economy: property rights and public policy*. Oxford: Blackwell; Hanna, S. & Jentoft, S. 1996. Human use of the natural environment: and overview of social and economic dimensions. In S. Hanna, C. Folke & K.G. Mäler (eds), *Rights to nature: ecological, economic, cultural, and political principles of institutions for the environment:* 35-55. Washington: Island Press.
5. Hanna & Jentoft. Human use of the natural environment: and overview of social and economic dimensions.
6. Committee of the Royal Anthropological Institute of Great Britain and Ireland. (6th Ed.) 1967. *Notes and Queries on Anthropology.* London: Routledge and Kegan Paul.
7. Hoebel, E.A. (3rd ed.) 1966. *Anthropology: The Study of Man.* New York: McGraw-Hill; Macpherson, C.B. 1978. The Meaning of Property. In C. B. Macpherson (ed), *Property: Mainstream and Critical Positions:* 1-14. Oxford: Basil Blackwell; Hann, C.M. 1998. Introduction: The Embeddedness of Property, in C.M. Hann (ed), *Property Relations: Renewing the Anthropological Traditions:* 1-47. Cambridge: Cambridge University Press.
8. Strang, V. & Busse, M. 2011. Introduction. In Veronica Strang & Mark Busse (eds), *Ownership and appropriation*: 1-19. New York: Berg.
9. Harvey, D. 2005. *A Brief History of Neoliberalism.* New York: Oxford University Press.
10. Hawken, P., Lovins, A.B. & Lovins, L.H. 1999. *Natural capitalism: the next industrial revolution*. Boston: Little, Brown and Co; Harvey. *A Brief History of Neoliberalism.*
11. Homer-Dixon, T. 2007. *The upside of down: catastrophe, creativity, and the renewal of civilization.* Toronto: Vintage Canada.
12. McCay, B.J. 1996. Common and Private Concerns. In S. Hanna, C. Folke and K.G. Mäler (eds), *Rights to Nature: Ecological, Economic, Cultural, and Political Principles of Institutions for the Environment*: 111-126. Washington: Island Press.
13. Strathern, M. & Hirsch, E. 2004. Introduction. In Eric Hirsch and Marylin Strathern (eds), *Transactions and creations: Property debates and the stimulus of Melanesia*: 1-18. New York: Berghahn Books; Strathern, M. 2011. Sharing, stealing and borrowing simultaneously. In Veronica Strang & Mark Busse (eds), *Ownership and appropriation:* 29-41. New York: Berg.
14. Lazlo, E. 2009. *World shift 2012.* Rochester: Inner Traditions.
15. Capra, F. 1996. *The Web of Life*. New York: Anchor Books; Mang & Reed. Designing from place: a regenerative framework and methodology.
16. Mang & Reed. Designing from place: a regenerative framework and methodology.
17. Ibid.
18. Robinson, J., Cole, R.J., Cayuela, A. & Kingstone, A. 2013. *The Centre for Interactive Research on Sustainability, UBC: Creating Net Positive Benefits at Multiple Scales.* Submitted for publication at CaGBC National Conference and Expo. Vancouver.
19. Mang& Reed. Designing from place: a regenerative framework and methodology.
20. du Plessis, C. 2009. *An approach to studying urban sustainability from within an ecological worldview.* Doctoral Thesis. Manchester: University of Salford; du Plessis, C. & Cole, R.J. 2011. Motivating change: shifting the paradigm. *Building Research & Information* 39(5): 436-449; Mang & Reed. Designing from place: a regenerative framework and methodology.
21. Kalundborg Symbiosis. *About.* (Available at http://www.symbiosis.dk/en) (Accessed on 23 July 2013).
22. Hann. Introduction: The Embeddedness of Property.

ISBN: 978-84-697-1815-5

23. Mang & Reed. Designing from place: a regenerative framework and methodology.
24. UBC Sustainability. 2010. *Climate Action Plan.* (Available at: http://www.sustain.ubc.ca/campus-initiatives/climate-energy/climate-action-plan) (Accessed on 6 January 2013).
25. Hanna & Jentoft. Human use of the natural environment: and overview of social and economic dimensions.
26. Pedersen Zari. Ecosystem services analysis for the design of regenerative built environments.
27. du Plessis & Cole. Motivating change: shifting the paradigm.

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Session 27:

What does construction of schools teach us about sustainable building?

Chairperson:

Zamora, Joan Lluís

Professor Universitat Politècnica de Catalunya

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ECO-SCHOOL MAX – Built with waste materials

Speakers:
Soriano, Marta, Camacho, Jesús.

ECOART-DIDACTIC, Barcelona, Spain,

Anstract: *On our planet we have lack of schoolss, lack of natural resources and a large excess of residual material.(imagenumber01.jpg)*

Building with wasted material is an excellent alternative to solve those problems.

imagenumber01.jpg

We plan to build our Eco-School MAX based on natural and residual materials, mainly empty glass bottles. (imagenumber02.jpg)

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imagenumber02.jpg

Many of our old social and economic structures are becoming obsolete and we are forced to reinvent our habits, our way of dedvelopment, our way to consume and our way to build. Our society needs a new operating system in the arquitectonic field. The actual system is running obsolete. It is urgent to do a RESET.

The Eco-School MAX, built with waste materials, is a model of eco-efficiency applied to architecture: it allows to clean the environment and to create more benefits and services in the community, using fewer resources and generating less waste.

The Eco-School MAX is also a model of sustainable architecture, applying several construction systems which are able to last over the time, respecting the environment and taking advantage of readily available sustainable materials and resources from its natural surroundings

It allows to fulfill the needs of the present generation without sacrificing the needs of future generations.

Keywords: Sustainable schools, Sustainable architecture, Natural resources, Sustainable designs and construction, renewable energy, Permaculture, self-sufficient buildings, recycling, sustainable architecture, radically sustainable living, greywater.

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Eco-School, build with wasted material

The first houses built with bottles date back to early 20th century. They were built during the gold rush in the mining towns of the desert, where the saloons and their empty bottles, were much more abundant than building materials. The use of bottles in the construction has been increasing since then, and today there are thousands of homes on the five continents.(imagenumber03.jpg, imagenumber04.jpg)

imagenumber03.jpg

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imagenumber04.jpg

So far it has not been possible to solve the immense needs of habitat and schools in many countries.

A solution coud be using local building materials and self building techniques.

It is necessary to introduce a term prior to the industrial revolution: ***frugality***. It does not mean poverty, but to make intelligent use of our resources. Consumerism must stop being the engine of our lives. We are producing an excessive volume of waste. One of the main solutions to reduce them is changing our attitude regarding construction and architecture. We need more awareness of who we are and what environmental impact we are causing to our ecosystems.

Let's face the challenge from eco efficiency, seeking zero waste, zero emissions and zero ecological footprint. Let's ask ourselves: How can waste be reused as raw material to build homes and schools?

A brief analysis of the industry and production system reveals that waste material will be in the future increasingly more abundant and diverse.

The goal of this Project, Eco-School MAX, is to observe waste, as a valuable raw material for the construction industry, specially for the costruction of schools.

The Eco-School MAX, will be build with diferent kind of residues, mainlyt recycled plastic (PET) bottles, integrated into conventional building systems such as concrete blocks and wood. (imagenumber05.jpg, imagenumber06.jpg, imagenumber07.jpg, imagenumber08.jpg)

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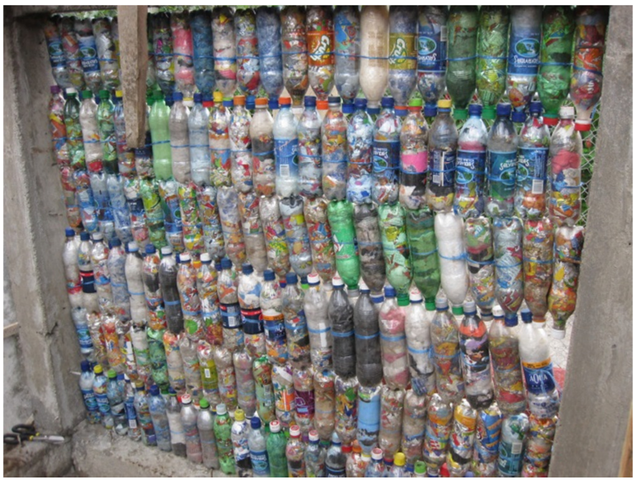
Higlhlights of this type of costruction are its resistance to earthquakes, tornadoes, floods or other natural disasters.

imagenumber05.jpg



imagenumber06.jpg

Buiding our Eco-School MAX represents a lot of advantages regarding many diferent aspects: Technological, social, economic and ecological.

<u>The economic aspect:</u> Building the Eco-School MAX with raw material is much cheaper than building with other traditional systems. It can improve the quality of life of the community reducing the cost of buildings materials.

imagenumber07.jpg

imagenumber08.jpg

The Eco-School MAX is designed as a structure free of centralized utilities. It is entirely self-sufficient. It collects rainwater which is filtered and used for drinking and other activities. Electricity is generated by solar panels and stored in batteries. This type of school contributes to huge savings in the utility bills, taxes, maintenance, building materials and furniture.

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<u>The educational aspect:</u> This kind of constructions require many helping hands, and these activities provide a range of knowledge and experience to many persons who have not had the opportunity to study anything in particular. This fact makes them experts in new building techniques, through the training they receive. A single qualified person who is in charge of the project is enough at the beginning. Later, all participants will be trained to leader their own projects themselves and to educate more people and have their own teams.

<u>The social aspect:</u> construction with waste also has a strong social aspect, it is an inclusive work, in which all members of a community can participate. Entire families come together for a project and they all learn the basic principles of construction.

<u>The ecological aspect:</u>

40% of the resources that are today drawn from nature are used for construction. The production of cement is today one of the most polluting in the planet and it contributes in a large scale to global warming.

Most plastics are not biodegradable, they do not break down naturally by the action of the agents of nature (fungi, bacteria, light of the Sun, etc.) and remain for a long time in the atmosphere. Specifically plastic and its derivatives is a hard recyclable material. A plastic bottle can last between three and five centuries before biodegrade.

In some countries plastics are burned, creating serious pollution and environmental problems. According information from United Nations sources, only 5% of the plastic is recycled.

Th Eco-School MAX has a high thermal insulation, which means a great energy saving. They enjoy passive air conditioning systems, its walls pick up the heat of the Summer, they expand it throughout the winter and vice versa. This characteristic is called thermal inertia.

<u>The participation aspect:</u> the construction of the Eco-School MAX with this type of techniques, is only possible with the participation of many people. Many hands and many hours of work are needed to complete this project. You have to motivate families and the neighboring communities to participate and feel involved in a project in common, for individual and collective well-being. All participants are important and, thanks to this effort in common, the standard of living of the community will raise.

The first school built with glass and plastic bottles is in the Philippines, Asia, (2010). It is a sustainable, inexpensive and disaster-resistant construction. Dozens of volunteers helped for the construction of the school. This project captured the attention of architecture and construction industry in the Philippines.

5,000 bottles were needed for the construction of the first classroom and it took about a month. The walls that separate the classrooms are made of bamboo fiber, corn leaves and rice husks mixed and rammed.

The workers mixed cement with human hair and chicken feathers, obtained from barbershops and poultry farms. This mixture is 95 per cent stronger than conventional cerment.

In Taguig, a city located in the metropolitan area of the capital Manila, they rebuilt a school destroyed by Typhoon Ondoy.

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Integrated value model for sustainable assessment of school centers' construction

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Abstract: *Hundreds of new school centers were built in Catalonia between 2000 and 2009. It was a governmental decision in order to solve an endemic lack of centers that in the early 2000s had worsen. Masonry and poured on site reinforced concrete structures were used to build most of these schools as it had been done previously. The novelty was the use of interesting off site construction processes such as prefabricated concrete, steel and wood technologies. These school edifices and their building processes were analyzed in the author's thesis in 2009. Later in 2011 the author analyzed the lyfe cycle process of the construction of these centers. In this paper the authors assess the sustainability of these schools using a dynamic evaluation tool optimized for this case study. This tool has been defined using the Integrated Value Model for Sustainable Assessment (Modelo Integrado de Valor para una Evaluación Sostenible - MIVES).*

Keywords: Sustainability, environmental impact, schools, construction

1. Introduction

In the 2000s architects were still enlightened by magnificent examples of high-tech architecture from the 70s and 80s, such as the Centre Culturel d'Art Georges Pompidou in Paris designed by R. Piano & R. Rogers or N. Foster's Stansted Airport in London. Meanwhile, new critical theories were written about this architecture built using high-tech and prefabricated construction systems. In 2002, N. Sinopoli (2002) explained the importance of the building process management itself in terms of reducing frames. Later S. Kieran & J. Timberlake (2004) adviced architects to leave a "century of failures" of off-site construction and join present's mass production with new icons such as airplanes industry. And C. Davies (2005) invited architects to learn from the anonymous prefabrication of mobile homes and bath pods instead of blindly following the celebrated high-tech architecture.

By then, new local exemplary architecture was built using off-site construction, taking advantage of its possibilities but without focusing the architectural expression or visual aspect in prefabrication itself. For example M. Ruisànchez & X. Vendrell's Riumar school of Deltebre in 1995 and P. Perez & M. Pàmies & A. Banús' Economic Faculty of Reus from 1994 to 1996. This architecture differed from all the schools previously badly built off-site, in the 60's in Europe & in the 70's in Spain. However, the educative community vively remembered those previous experiences and was completely against using prefabricated systems to build schools. But the most important and active social opposition was against the intensive use of poorly conditioned prefabricated provisional modules ("barracons") for public schools. From the 90s on more than 800 "barracons" were used each year in order to solve an endemic lack of educational centers. This situation had worsen due to important

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irregular unforeseen migratory movements, 1.000.000 people came from North Africa, South America and Eastern Europe while many families left cities to live in smaller villages.

Finally, in 2002 the government decided to build hundreds of new school centers to solve this severe lack of schools. These new schools were built following tight frames and, therefore, the contractual process was necessarily simplified. However, each school had an individual architectural design in which the future educational team was invited to participate. But the critic frames and low budgets minor the social an environmental aspects of the designs.

This research paper exposes a sustainability assessment of these schools. This assessment was presented in Pons et al., 2012.

2. School buildings and their construction processes

This research considers a sample of 384 preschool and elementary public school edifices built from 2002 to 2009 in Catalonia. This sample was previously studied in the author's thesis (Pons, 2009) concluding that these educational buildings had been designed following strict standards from the gobernment. These standards determined their surface area (6 to 7 m^2/ student), their spaces (number and type of classrooms, gymnasium, dining room, offices,etc.), their volumetry (rectangular 3 storey elementary building, a single storey U-shaped preschool edifice, rectangular 4,5 m high gym building,), etc. In consequence, these school edifices could be rigorously studied by classifiying them according to the technologies used to build them. In Table 1 and Fig. 1 there is this classification and the use of these technologies to build these 384 schools respectively. Both show that most schools were built using poured on site reinforced concrete structures and less using concrete, steel and timber off-site structures.

Process	Structural material	Structural typology	Percentage of schools (%)
On site technologies	Structural Concrete	Frames	58,0
		Columns and slabs	
Prefabricated technologies	Structural Concrete	Frames	22,7
		Load-bearing walls	
		Load-bearing room modules	
		Load-bearing walls & modules	
	Structural steel	Frames	19,0
		Load-bearing room modules	
	Structural timber	Load-bearing walls	0,3
		Load-bearing walls & modules	

Table 1. Classification of the technologies used to build these 384 school centers.

This study will focus on the technologies used to build most of the school's structures which are: the onsite concrete structure technology (OC); the prefabricated concrete framed structure technology (PC), and the prefabricated steel modules structure technology (PS). This research project also studies the prefabricated timber structure system (PT) because, although having been less used, it is based on a different material with an outstanding environmental behavior.

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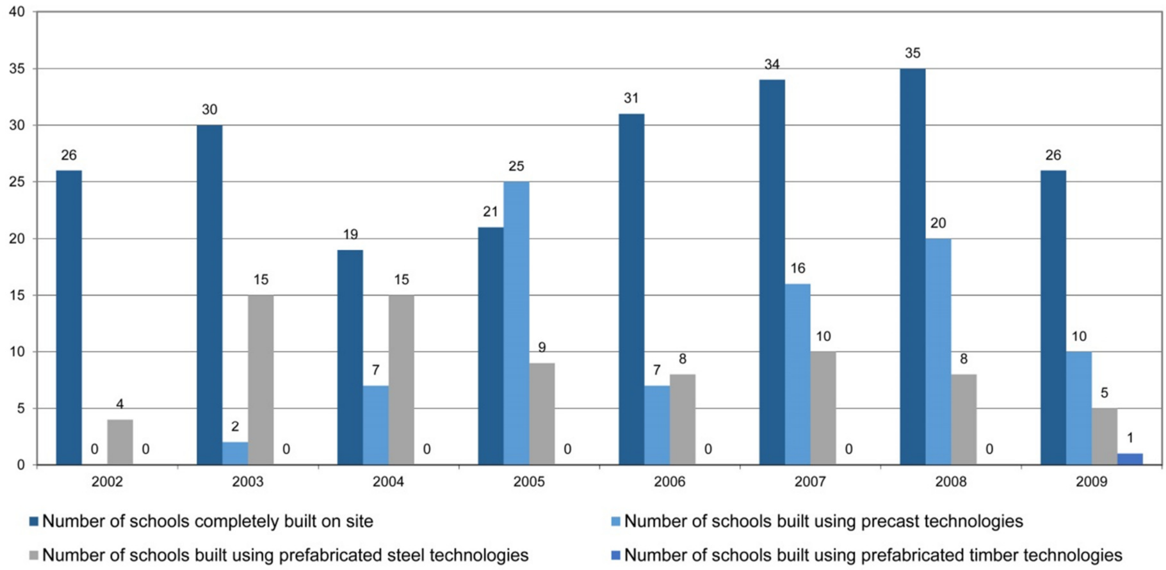

Figure 1. Number of schools built using on site and prefabricated concrete, steel and timber technologies.

Educational centers build using OC have a poured in situ reinforced concrete hyperstatic structure, which is either bidirectional – with columns and waffle slabs – or unidirectional – with frames and ribbed floors. Columns have square sections from 30 x 30 to 40 x 40 cm and distant one to the other up to 7 m. Floors can either have a uniform height of 30 cm or be 25 cm high with beams 45 cm high. Schools constructed utilizing PC have a prefabricated reinforced concrete isostatic unidirectional structure composed of frames and hollow core slabs. Frames have continuous columns each 6 m maximum, with orthogonal cross sections from 40 x 40 m to 60 x 60 m. Beams have the columns base; up to 40 cm of its height is precast and visible while the other part is embedded in the floor, which has a topping layer poured on top of the hollow core slabs and beams. Slabs are 16 to 40 cm wide and they span up to 12 m.

Educational centers build using PS are composed of steel room modules with a maximum size of 3.2 x 3.65 x 18.4 m. These modules have square hollow section columns – for example 140.140.6 – welded to hot-rolled section beams – UPN 270 – which contain a composite slab – for example 12 cm wide. Schools built utilizing PT have a timber structure composed of structural walls, load bearing room modules and slabs. Walls are 57 to 158 mm wide massive laminated timber panels whose area measures 2.95 x 16.5 m maximum. Room modules have several of these structural walls and one or two slabs. Floor slabs are 60 to 248 mm wide laminated timber also 2.95 x 16.5 m maximum.

3. Analysis

Researchers aimed to find the building technology which had the lowest environmental, economic and social impact in the construction of hundreds of preschool and elementary centers. To do so there was the possibility of using an existing tool so the best tools to assess the object of study were analysed – BREEAM, CASBEE, DGNB-Seal, EcoEffect, Green

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Globes, Green Star, HQE, BEAM, LEED, VERDE. To analyse them the reseachers took into account previous reviews and if the tool: was complete and included environmental, economic and social indicators, if it was possible to assess school buildings, etc. These 13 tools and their predecessors have contributed to move forward to a more sustainable architecture. They have brought methodology and they have contributed to raise awareness in the construction sector, but their influence mainly bears on the need to reduce the environmental impact.

3.1. Sustainability assessment of the case study

Following the results of this analysis of assessment tools, the researchers decided to use a new tool based on the Integrated Value Model for Sustainable Assessment (MIVES), which is a Multi-Criteria Decision Making Method that has already been applied to several areas, such as the Spanish structural concrete standards (Aguado et al. 2013). MIVES was chosen mainly because it permitted fast assessments for edifices with tight timeframes, such as the schools of this sample.

Following MIVES, the decision making tree in Table 2 was built, which includes only the main and the most discriminatory indicators, so it is adequate to obtain a correct assessment decision because indicator amount is not excessive.

Requirements	**Criteria (%)**	**Indicators**
R1. Economic (50%)	C1. Cost (52%)	I1. Production and assembly cost (30%)
		I2. Cost deviation probability (25%)
		I3. Maintenance cost (45%)
	C2. Time (48%)	I4. Production and assembly timeframe (38%)
		I5. Timeframe deviation probability (62%)
R2. Environmental (30%)	C3. Phase 1: extraction and fabrication of materials (30%)	I6. Water consumption (22%)
		I7. CO_2 emissions (40%)
		I8. Energy consumption (38%)
	C4. Phase 2: transport (10%)	I9. CO_2 emissions (100%)
	C5. Phase 3: building and assembly (15%)	I10. CO_2 emissions (58%)
		I11. Solid waste (42%)
	C6. Phase 4: use and maintenance (30%)	I12. CO_2 emissions (100%)
	C7. Phase 5: end of life (15%)	I13. Solid waste (100%)
R3. Social (20%)	C8. Adaptability to changes (35%)	I14. Neither adaptable nor disassemble building percentage (theoretical) (50%)
		I15. Deviation of neither adaptable nor disassemble building percentage (50%)
	C9. Users' safety (65%)	I16. Labor risk of accidents (40%)
		I17. Users risk of accidents (60%)

Table 2. Decision making tree for the sustainability assessment of the studied schools.

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Economic requirement includes 5 indicators which evaluate: construction and maintenance cost over 50 years, construction timeframes and the probability of deviation in both. The cost of school edifices usage is not taken into account because it is not discriminatory. The end of life cost has not been included either because it is considered account in the environmental indicator I13. The environmental requirement considers 5 LCA phases: 1) extraction and production; 2) transport; 3) construction and assembly; 4) use and maintenance over 50 years; 5) end of life. This requirement is based on a simplified LCA about these 4 technologies (Pons et al 2011) that from the 5 life cycle phases studies 4 indicators: CO_2 emissions, energy consumption, water consumption and solid waste production. Only the most important and discriminatory indicators for each phase are considered. For example, water consumption during the construction and assembly phase is not included because, in the most unfavorable case, it is less than 0.01% of the whole life cycle water consumption. Social requirement includes 4 indicators which assess: technologies capacity to disassemble and change their parts during the school building's usage and this capacity probability of deviation; construction and assembly accident risk. Some social indicators have been not included because they were not discriminatory, such as the ease to enlarge edifices or the industry workers' safety.

These 3 requirements, 9 criteria, 17 indicators and their weights (λi) were decided during various seminars of experts. A value function (Alarcón et al) was designed for each indicator, relying on numerous and rigorous bibliography. Although the 17 indicators have different units, all their value functions vary from 0 to 1, 0 being the minimum satisfaction and 1 the maximum satisfaction for each indicator. These adimensional values Vi(xi) can be aggregated in order to obtain the global sustainability index *V* from equation 1.

$$V = \sum \lambda_i \cdot V_i(x_i) \qquad [1]$$

These 17 value functions depend on 5 parameters, as shown in equation 2. These parameters define its shape and therefore how each indicator value variation is translated to the adimentional scale. Then, if the function shape is an S, then the initial and final indicator value variation will have an adimensional value variation smaller than the middle value variation.

$$V_{ind} = A + B \cdot \left[1 - e^{-ki \cdot \left(\frac{|Xalt - X\max|}{Ci} \right)^{Pi}} \right] \qquad [2]$$

In equation 2, A is the response value Xmax (indicator's abscissa), and Xalt is the assessed indicator abscissa which gives a value Vind. Pi is a shape factor that determines if the curve is concave, convex or shaped as a "S". Ci establishes, in curves with Pi>1, abscissa's value for the inflexion point. Ki defines the response value to Ci. B is the value that keeps the function in the range from 0 to 1 and it is defined in equation 3.

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$$B = \left[1 - e^{-ki \cdot \left(\frac{|X\max - X\min|}{Ci} \right)^{Pi}} \right]^{-1} \qquad [3]$$

From the 17 value functions, 8 decrease convexly (CvxD), 5 decrease lineally (SD) and 4 decrease concavely (CcvD). Convex functions are for indicators which the administration accepts a partial satisfaction, such as: construction timeframes, environmental indicators… On the other hand, concave functions represent indicators which the administration demands a maximum value, such as safety. Decreasing functions have 0 as the most satisfactory value and take the worst value of the studied systems as the least satisfactory.

4. Results and discussion

Assessing the four main technologies used to build the schools of the sample using the aforementioned MIVES tool we obtain their sustainability indexes, which are shown in Table 3 and are applicable to the schools in this sample. These indexes show that these technologies could improve in the following way:

- Precast concrete system ought to improve: environmental indicators mainly from phase 1 extraction and production; and social indicators, firstly its low adaptability and reversibility.
- Prefabricated steel technology should improve: environmental indicators from phase 1 and from phase 2, reducing the distance from site to factory; and ought to reduce the distance from site to industry.
- Word technology should improve: environmental indicators from phase 2 and economic indicators such its durability and maintenance.
- On site concrete system should improve most of its indicators: economic (timeframes, etc.), environmental (construction waste, etc.) and social indicators (flexibility and risk of accidents).

Technology	Requirement			Global index	Application (%)	Sustainability
	Economic	Environmental	Social			
PC	0.83	0.64	0.55	0.72	22,7	Major
PS	0.81	0.51	0.78	0.71	19,0	
PT	0.53	0.58	0.73	0.59	0,3	
OC	0.38	0.41	0.17	0.35	58,0	Minor

Table 3. Sustainability indexes of the building technologies used to construct the schools of the sample.

The application of these 4 construction technologies to build the schools of the sample does not respond to sustainability index, because these schools were built without considering sustainability criteria. Studying the sustainability assessment results relying on rigorous an extended studies about these schools (Pons 2009) we can conclude that the application of these systems depended on three factors: a) political, social and technical rejection of prefabricated technologies; b) factory and contractor productive and executive capacity and c) a recently implemented PT system.

5. Conclusions

The sustainability assessment tool defined in this research project is specialized for the sample; quick; takes into account applying this technology in the architectural design process and in the finished school; gives both global and partial detached indexes. The authors consider that this methodology could be able to assess similar samples if previously reconfigured.

To build these sample educational centers: a) prefabricated concrete and steel processes are the most sustainable; b) the wood technology applied has an unexpectedly low index, being an exemplar building system that, for this object of study in which the production center is remote (1600 km), is not the best option; c) on site concrete building process is the least sustainable proces and should be improved before using it again. Therefore, this investigation project’s results are different and new from previous sustainability assessments on prefabricated technologies.

This investigation could be used so that in the near future educational centers would be constructed following sustainability reasons. The application of the tool defined in this study could result in having better future school centers.

6. References

Aguado, A.; del Caño, A.; de la Cruz, P.; Gómez, P.J.; Josa, A. (2012). Sustainability assessment of concrete structures within the Spanish structural concrete code. J Constr Eng M Asce; 138(2): 268–76, doi:10.1061/ (ASCE) CO.1943-7862.0000419.

Alarcón, B.; Aguado, A.; Manga, R.; Josa, A. (2011). A Value Function for Assessing Sustainability: Application to Industrial Buildings. Sustainability, 3: 35-50.

Davies C. (2005). The Prefabricated Home. London. Reaction Books.

Kieran S. & Timberlake J. (2004). Refabricating architecture: How manufacturing methodologies are poised to transform building construction. New York. McGraw-Hill Professional.

Pons, O., Aguado, A. (2012). Integrated value model for sustainable assessment applied to technologies used to build schools in Catalonia, Spain. Building Environment, 53: 49-58, doi:10.1016/j.buildenv.2012.01.007

Pons, O.; Wadel, G. (2011). Environmental impacts of prefabricated school buildings in Catalonia. Habitat International, 35: 553-563, doi: 10.1016/j.habitatint.2011.03.005

Pons, O. (2009). Arquitectura escolar prefabricada a Catalunya (Prefabricated school buildings in Catalonia). Director: González JM. PhD thesis. Barcelona, UPC. Digital version at: “http://www.tesisenxarxa.net/TDX-0219109-114725/”

Sinopolis, N. (2002). La tecnologia invisibile. Il processo di produzione dell'architettura e le sue regie. Milano. Serie di architettura FrancoAngeli.

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Users impact on energy and water consumption in Portuguese school buildings. From assessment to strategy

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Abstract: *The increase of complexity in school buildings to support user comfort and social and functional demands is changing the resources consumption patterns, namely energy. Users indoor comfort conditions also play a significant role in energy demand in school buildings. A significant number of Portuguese public secondary schools were recently refurbished, under a national modernization program. The present paper shares the main results of a multiple case study, comprising eight secondary schools, regarding resources use monitoring (energy and water) and the observational field work concerning users' attitudes and behaviour.Promoting best practices to enhance school buildings sustainability has a double goal: addressing the environmental impact of a large stock of service buildings and simultaneously raise awareness among the younger generations.*

Key words: energy, water, schools, user, behaviour

Introduction

The increase of complexity in school buildings to support users comfort and social and functional demands is changing the resources consumption patterns, namely energy. Several research studies regarding energy use in schools conclude on a rising tendency, in particular associated with an increase in electricity use. A more intensive use of IT as pedagogical tools, an increase in equipment loads and artificial lighting use are refered in different countries [1][2]. Also indoor comfort conditions, in particular regarding temperature and air quality, play a significant role in energy demand in school buildings [3]. School buildings are a particular sensitive typology regarding buildings users' environmental impact. The energy and water consumption monitoring in school buildings has been revealing significant energy gaps [4] and variations [5] among cases, confirming such impact.

Understanding users/buildings interaction is crucial to promote sustainable design strategies. Promoting best practices to enhance school buildings sustainability has a double goal: addressing the environmental impact of a large stock of service buildings and simultaneously raise awareness among the younger generations.

A significant number of Portuguese public secondary schools were recently refurbished, under a national modernization program (SPM) [6]. These schools have been rehabilitated in accordance with the Directive 2002/91/EC on the energy performance of buildings. The

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monitoring of the process itself was relevant to feed a data base that can allow critical assessments and draw conclusions for future school buildings rehabilitation programs and facilities management policies. User behaviour and strategies, regarding the interaction with the schools facilities, was the main scope of a research project, while the resources use environmental impact was the main concern. The present paper shares the main results of a multiple case study, comprising eight secondary schools, regarding the resources use monitoring (energy and water) and the observational field work concerning users' attitudes and behaviour.

Methodology

Nowadays monitoring use and resources metering is potentially producing a significant body of quantitative data. One of the challenges, not yet consistently addressed, is the development of research methodologies that allow drawing meaningful and operative conclusions from such data. Scientific studies [7] [8] point out that simply presenting resources use information and Key Performance Indicators (KPI's) is not enough to trigger improvement actions.

A multiple case study approach allowed a crossed analysis of the schools energy and water performance assessment (KPI's) with user behavior through a post-occupancy observational study. This lead to the identification of potential Key performance Strategies (KPS's) to promote the schools environmental sustainability through user behavior.

Case study presentation

Table 1 presents the Portuguese public secondary schools main building typologies and construction period. The selected cases represent the three main public secondary schools building typoplogies. Seven of the selected schools (S1 to S7) are schools rehabilitated under the SPM. The eight school (SB) has not been refurbished and was added as a blank case. The eight schools are presented in Figure 1. The SPM program included new integrated mechanical ventilation and acclimatization systems to comply with the legal standards for air renovation rates and comfort conditions regarding indoor spaces. The total built area increased for all the rehabilitated schools, as new functional areas, such as auditoriums and libraries were added.

Table 1.Secondary schools buildings typologies and construction period.

Building typology	*(A) Historical lyceum*	*(B) Technical schools model*	*(C) Pavilion model*
Schematic plan			
Construction period	*Late XIX c. - 1930's*	*1934-1969*	*1970-1990's*

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Figure 1. The eight schools comprised in the multiple case study and respective typology.

Data collection and treatment

Energy and water consumption was collected considering five consecutive years: before (2008), during (2009-2010) and after the refurbishment (2011-2012). Regarding the blank case, energy data collection refers only to 2011 and 2012, in order to compare this school energy use with the refurbished schools. Electricity consumption was collected through metering while gas consumption was collected through the monthly bills. In the Results section the total annual energy and water consumption is presented for each school. For performance comparing among the cases annual energy consumption is normalized by surface area and water consumption is normalized by number of students. The energy consumption CO_2 equivalent emissions are also normalized by number of students.

Walkthrough visits and semi-structured interviews were conducted in the eight schools. The schools directors, operational staff and each school project designer team leader were interviewed. Based on the crossed analysis of the schools energy and water consumption performance and the actions, strategies and users motivations regarding their interactions with building and systems, potential improvement strategies associated with user behavior (KPS's) are proposed in the Conclusions section.

Results & Discussion

Energy and water consumption performance in the schools

Energy (electricity and gas) and water consumption before (2008) and after (2012) the rehabilitation is presented in Table 2. Figures 2 to 4 present the consumption evolution throught the monitored period while Figures 5 to 7 present the schools' comparative normalized performance after the refurbishment (2012).

Before the refurbishment the average annual energy consumption in the schools was 41kWh/m^2/year and after the refurbishment it raised to 67kWh/m^2/year. Electricity raised, in average, 200% and is the main energy source used in the schools. Gas consumption registered the highest increase after the refurbishment; 322% between 2008 and 2012. Only associated with water heating and cooking before the refurbishment, gas is now also used for space heating in some schools (S1, S3, S6). The CO_2 eq. emissions increased 239%, between 2008

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and 2012, corresponding to an average of 144.511 KgCO2/year in each secondary school in 2012 (67 $KgCO_2$/stundent/year or 18 $KgCO_2/m^2$/year).

Table 2. Resources consumption before (2008) and after the refurbishment (2012).

	Electricity				Gas				Water			
	2008		2012		2008		2012		2008		2012	
School	kWh	kWh/m²	kWh	kWh/m²	kWh	kWh/m²	kWh	kWh/m²	m3	m3/student	m3	m3/student
S1	97.000	14	473.877	54	35.207	5	285.904	33	10.727	15	6.349	5
S2	229.519	46	442.047	64	45.010	9	71.930	10	6.662	9	4.334	3
S3	122.864	21	267.736	35	34.354	6	174.761	23	2.986	4	3.685	4
S4	270.298	58	337.996	42	33.754	7	51.499	6	3.925	3	7.423	5
S5	293.862	39	499.033	63	30.840	4	21.159	3	9.087	8	4.439	3
S6	147.265	34	379.139	64	19.015	4	176.131	30	3.532	3	4.127	4
S7	235.540	33	379.862	35	61.364	9	55.627	5	2.263	2	4.899	4
$\overline{S1,S7}$	199.478	35	397.099	51	37.078	6	119.573	16	5.597	6	5.036	4
std (S1,S7)	76.621	-	80.781	-	13.165	-	95.384	-	3.282	-	1.350	-
SB	-	-	188.434	63	-	-	39.562	13	-	-	4.903	8

Thewes et al [1] refer average European schools electricity consumption values from 10 to 30 kWh/m^2/year, which are below the present cases both before and after the refurbishment (35kWh/m^2/year and 51kWh/m^2/year). The same authors refer 100 kWh/m^2/year as a reference for heating consumption in the schools. Such value is quiet above the gas consumption in the present case study after the refurbishment (16kWh/m^2/year) and even above the total energy consumption (67kWh/m^2/year). Although the Portuguese school cases present lower total energy use, the increase in the consumption trend (+218% between 2008 and 2012) confirms the need to monitor this particular building typology, as defended in other contexts [1][2].

The schools introducing gas for space heating registered an average increase of 719% and were responsible for 76% of the total gas consumption, considering the seven refurbished schools (Figure 3). These schools also show a higher variation between 2011 and 2012, revealing the attempt to adapt to the newly introduced heating system.

Regarding water use patterns, after the refurbishment the consumption decreased, in average, by 10% (Table 2). The water supply system renovation had a significant impact in the demand reduction. When considering both the raise in student's number per year between 2008 and 2012 in the schools - 137%, in average - and in built area - 141% - a raise in water demand should be expected. But contrary, the total annual consumption decreased in three modernized schools (S1, S2, S5). The relatively similar total water use in the blank case (SB), where there are no sport facilities and showers, when comparing to the refurbished schools indicate that the factor "water supply system" was a major factor impacting water demand before the refurbishment. The comparative water consumption performance between the refurbished schools and the blank case emphasizes this conclusion (Figure 7). The water systems refurbishment also homogeneized consumption, as the variation among the cases reduced from 4,74x in 2008 to 2,01x in 2012. In two schools (S3, S5), between 2011 and 2012, the schools administrations introduced policies for water systems supervision and active

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management (taps flux in the bathrooms and showers were adjusted) leading to an additional reduction of about 33% in these schools annual water consumption (Figure 4). Other studies on water use in school buildings had reached similar conclusions, relating the water systems renovation with significant demand reductions [5] [9].

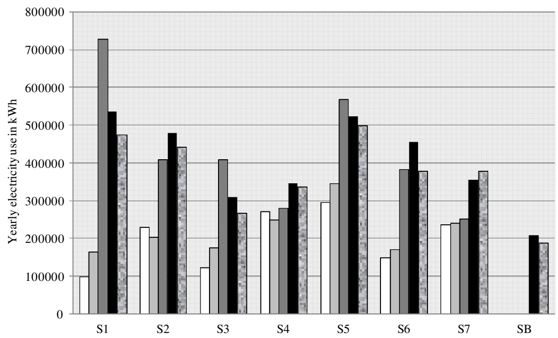

Figure 2. Annual electricity consumption in the schools between 2008 and 2012

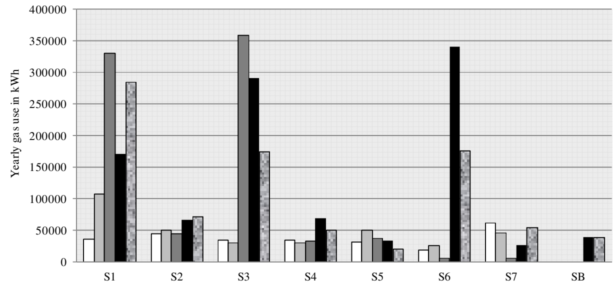

Figure 3. Annual gas consumption in the schools between 2008 and 2012

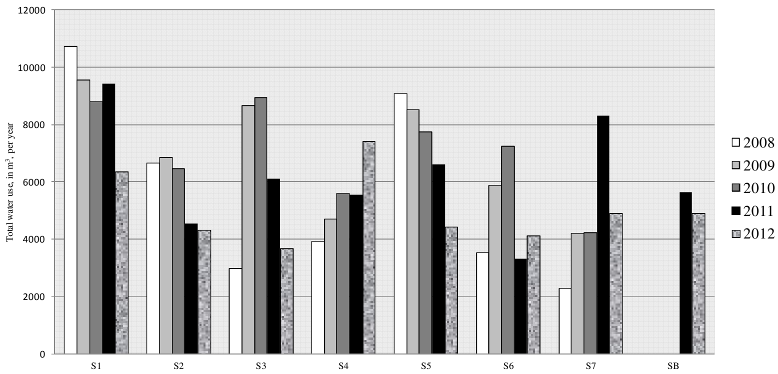

Figure 4. Annual water use in the secondary schools between 2008 and 2012

Users' attitudes and behaviours

When inquired about energy and water management in the schools all the administration board members, revealed that economical factors were their main concern, especially regarding the energy consumption increase after the refurbishment.

Economical factors were the main drivers for developing strategies to reduce energy while environmental awareness is more frequently associated with water use.

Because electricity unitary costs are higher than gas, school directors revealed higher concern with the electricity rise and were less aware of the gas increase, even though it was substantially higher in some cases. Most directors revealed that they did not have a consistent knowledge about the schools' resources consumption patterns and they all stated to have none on benchmarks regarding energy and water consumption in school buildings. Significant variation in the monthly bills (cost) is an awareness trigger for potential inefficiency detection, both for energy and water.

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<u>*Because there is not a consistent benchmark data disclosure and communication regarding the resources use in the Portuguese schools, users can not make grounded assessments regarding their behaviour and the schools performance.*</u>

Regarding the tools available for systems management, in some cases computerized BMS (Building Management Systems) were installed to manage the HVAC systems (S1, S2, S5, S6), in one other case to manage both HVAC and lighting systems (S4), while others schools maintained a manual operation of both HVAC and lighting systems (S3, S7). This means different levels of management perception and feed-back, from a holistic and broader knowledge of the entire facilities status to “blind management”.

<u>*Although the rehabilitated schools have now similar installed equipments, users have different tools to control their comforts conditions and manage energy use.*</u>

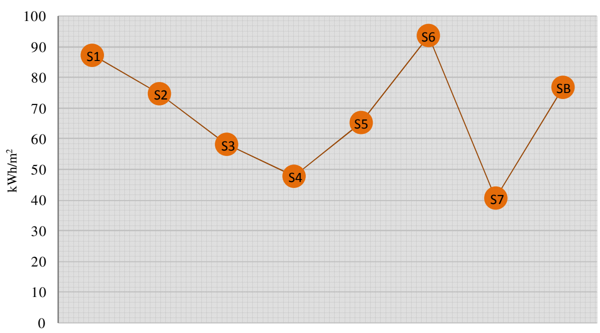

Figure 5. Schools KPI’s: energy consumption, normalized by surface area

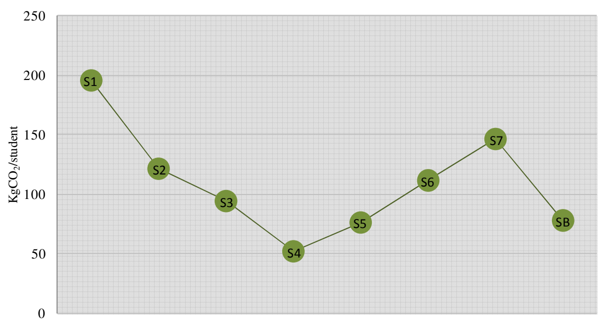

Figure 6. Schools KPI’s: energy consumption equivalent $KgCO_2$ emissions, normalized by number of students

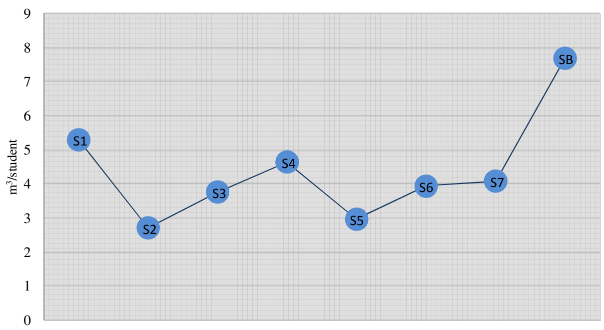

Figure 7. Schools KPI’s: water consumption, normalized by number of students (2012)

Conclusions: Potential Key Performance Strategies for a sustainable resources use in school buildings

i. Valuating information and communication: feed-back and knowledge transfer

The present case study points out the relevancy that the positive action-reaction loops have for users to feed forward and orient their future interactions with buildings. The research allowed identifying that the lack of knowledge transfer among stakeholders and benchmark information disclosure is preventing users to make grounded assessments regarding their own behavior.

ii. From environmental awareness to proficiency

The valuing of environmental issues together with the above mentioned users' proficiency regarding the systems and resources management emerged as an apparently necessary combination for going from environmental awareness to action.

iii. Systems' usability and adaptability

The school users have different tools to manage energy and control their comfort conditions. Having a BMS does not necessarily mean more efficiency and comfort. The combination of the former strategies (i+ii) seem to be a prior necessary condition for an efficient and more sustainable use of the BMS. The case study analysis presents evidence that a proficient use of a BMS integrating HVAC and lighting management can have a positive impact in the schools energy performance.

iv. Acknowledging different users' profiles, different needs and comfort standards: customizing

One school with computerized BSM is feeding the system with more detailed and customized input data, based on user feed-back (S4). This allows the setting of customized comfort standards considering different users, performing different tasks, in different spaces, with different schedules. In the present case, the quality of the BMS input data and standards customization seems to be impacting positively the school energy performance and users satisfaction.

References

[1] A. Thewes, S. Maas, F. Scholzen, D. Waldmann, and A. Zürbes, (2014) Field study on the energy consumption of school buildings in Luxembourg, *Energy and Buildings*, vol. 68, pp. 460–470, doi: 10.1016/j.enbuild.2013.10.002

[2] J. Dobson and K. Carter (2010) An Attitudinal and Behavioural Study of Scottish Pupils in Regards to Energy Consumption in Schools in *CIB World Building Congress*, pp. 127–137.

[3] M. Santamouris, G. Mihalakakou, P. Patargias, N. Gaitani, and K. Sfakianaki (2007) Using intelligent clustering techniques to classify the energy performance of school buildings, *Energy and Buildings*, vol. 39, pp. 45–51, doi: 10.1016/j.enbuild.2006.04.018.

[4] R. I. of B. Architects and C. I. of B. S. Engineers, http://www.carbonbuzz.org/.

[5] C. L. Cheng and Y. T. Hong, (2004) Evaluating water utilization in primary schools, *Building and Environment*, vol. 39, pp. 837–845, doi: 10.1016/j.buildenv.2004.01.006

[6] A. Blyth, R. Almeida, D. Forrester, A. Gorey, and G. Hostens (2012) Modernising Secondary School Buildings in Portugal, *OECD Publishing*.

[7] S. Christina, A. Dainty, K. Daniels & P. Waterson (2014) How organisational behaviour and attitudes can impact building energy use in the UK retail environment: a theoretical framework, *Archit. Eng. Des. Manag.*,vol.10, pp.164–79,doi:10.1080/17452007.2013.837256

[8] K. Gram-Hanssen (2014) New needs for better understanding of household's energy consumption – behaviour, lifestyle or practices? *Archit. Eng. Des. Manag.*, vol. 10, no. 1–2, pp. 91–107, doi: 10.1080/17452007.2013.837251

[9] I. Omambala (2010) Evidence Base for Water Efficiency Water Efficiency Retrofitting in Schools, Waterwise, UK.

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From Single Building to Master Plan. Policies for Transformative Refurbishment of School Building Stocks

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Abstract:
Based on the analysis of evaluation of two different refurbishment strategies for school building stocks, this paper will present master planning approach as an innovative, long term planning strategy, which ensures both preservation of existing material and spatial resources as well as enables innovative transformation of the school as an institution.Traditional refurbishment practices in schools were, until recently, limited to single buildings, and applied identical norms for each building, regardless of age class and use class (typus). In Vienna the "substance renovation program" was adopted in 2008. In Zürich, a specific path to 2000 Watt society for schools is being examined. A third approach - master planning – allows a combination of different standard enhancement measures as well as functional and organisational reprogramming for different types of school buildings within the portfolio. All three strategies will be described and the advantages of each approach will be critically discussed.

Keywords: School buildings, refurbishment, strategy, master planning

Introduction

School building stock, as a part of the educational sector, is an essential public asset. In different countries across Europe, both school building stocks as well as school traditions are highly diverse. However, the two main goals of education is the same everywhere: firstly, to enable students to achieve skills and knowledge necessary for active participation in society (1) and secondly, to establish equal opportunity for all students, regardless of their socio-economic background. Since 18th century when compulsory education was introduced in most European countries, and since 19th century, when large proportions of the school building stock still in use were built, teaching and pupils needs have changed significantly. Personalized leaning is more and more replacing teacher centred instruction. Educational policy accepted the fact that school classes are highly heterogeneous and adopted teaching techniques in primary and secondary schools accordingly. However, this radically modified teaching practice had no impact on school design in German speaking countries. In spite of some notable exceptions, school buildings are still based on a separated classrooms with a teacher centred layout. This applies to all age classes of the 20th century.

Due to a large number of existing school buildings, the school of the future will take place in historic school buildings from 19th and 20th century. This particular public building stock is currently facing many challenges. Due to high personnel costs in education, for school stock are limited. In growing cities, such as Vienna and Zürich, which are examined in this paper,

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there is a pressure to build new schools, particularly in areas with new housing projects. Current classroom are considered large enough since the maximum number of pupils per classroom has been reduced. However, traditional classrooms are ill suited for individual and group instruction and alternatives to teacher-centred education. There are also no adequate working areas for teachers nor provisions or facilities for full-time school in both old and newly constructed schools. Educational research shows that full-time offers significantly improve equal opportunity and reduce risk for pupils from weak socio-economic backgrounds. Even if demographic growth will decrease in the future, there is a considerable need for additional and/or reorganized floor space in existing school buildings. The old school building stock, which is already partly affected by a substantial renovation backlog, is therefore not fit for emerging, innovative teaching practices. In addition to these fields of action, there is a need to address the challenge of low carbon and energy efficient refurbishment, as school buildings are publicly owned and must therefore fullfil EU energy requierements

How do current refurbishment strategies and concepts address these conflicting fields of action? Two very different approaches to school building stock refurbishment in Vienna, Austria and Zürich, Switzerland were examined and analysed. Long term value preservation or even value enhancement of the school building stock can only be achieved by taking into account both sustainable measures, as well as adaptation for future pedagogical demands.

Substance renovation in Vienna

The municipaly of Vienna owns and manages more than 300 school buildings for compulsory education, with a total area of 1.723.000 m2. (Table 1) A very large majority of the stock - 59% - was built between 1848 and 1918, the so called "Gründerzeit" era (period of promoterism).

Age class	Number	%
1848-1918	178	59,14%
1919-1944	5	1,66%
1945-1959	13	4,32%
1960-1969	26	8,64%
1970-1979	31	10,30%
1980-1989	9	2,99%
1990-1999	33	10,96%
2000-2005	6	1,99%
Total	301	

Tabelle 1: School buildung stock in Vienna, compulsory school building, source: MA 56, Vienna

Since 2001 the city of Vienna is continuously growing with a population gain of approximately 10% between 2001 and 2011. (2) The demografic prognosis predicts further population gains until 2050. The demografic growth is based on the influx of younger migrants and on birth surplus. Additionally, the maximum number of pupils per classroom

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was lowered from 30 to 25 in 2008. All this contributed to a large demand on additional classrooms and futher intensive use of existing school buildings. However, due to high personel costs in education, financial means for investments in school buildings in Austria are quite limited. In comparison to OECD states with an average share of 8,7 %, the share of investment costs in educational sector are sinking continuously since 2001, and curreny constitute a mere 2,2 % of total educational expenditure. (3). Limited means for periodic maintenance inevitably leads to a renovation backlog in the less robust and resilient parts of the stock. City of Vienna carried out major renovations on a limited number of building since 2000. However, limited funding did not allow to carry out major general renovations on the entire stock of older school buildings. In 2008 the municipality decided to adopt a strategy of "substance renovation". The main objective of this strategy is to repair severe construction and HVAC defects and further implement some standard enhancement measures in fire safety and barrier free accessibility. Between 2008 and 2017 a total of 242 schools will be repaired with a designated investment budget of 570 Mio. Euro. “Substance renovation” programme is based on a catalogue consisting of 17 different repair, maintenance, fire safety and limited energy efficiency measures. There is no provision for organisational re-programming of school layouts. (4)

Long term transition strategy in Zürich

There are 120 public school buildings in Zürich. A large proportion (more than half) of these municipal school building stock is under monumental protection. (5). In addition to a large number of the pre-war buildings under monumental protection, even a large share of post-war modernist buildings are listed. In Zürich, there is an increasing demand for additional housing but also for more school buildings, as the area belong to areas with strong demographic growth. "More pupils, changed teaching concepts and aged school buildings were the main reasons to initiate the school building programme in 2006". (6) Since then the city carried out major renovations on some of the pre- war school buildings. At the sites of some of the post-war modernist schools with extensive open spaces, new annexes were built and existing school wings were refurbished. One of the larger schools - Michbuck - originally built in 1929, was refurbished to a very high energy efficiency standard (close to Minergie-p standard). In 2008 the city of Zürich adopted a general strategy for transition to low carbon society, called "2000 Watt Society." The major goal is to reduce energy consumption from currently more than 6000 Watt per person to 2000 Watt by 2150. Due to a high percentage of listed building in the school building portfolio, an alternative concept was developed for this specific part of the public building stock. Instead of aiming for identical standards in all building regardless of age class and construction specifics, this concept adopted a portfolio-based approach. The aim is to achieve the general goal of emission and energy consumption reduction on the level of the whole portfolio and not for every single building. The construction department tested this approach in a study. Three different refurbishment models were defined and calculated on 11 actual buildings. The results were then extrapolated to the whole portfolio. (7) (8)

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Comparative analysis

Maintenance and repair are at the core of the Viennese substance renovation approach, which can be classified as a low level maintenance strategy according to König et. al.(9) The measures are rather general, with no relation to the non-homogenous building stock and different degrees of robustness and resilience within the stock. In spite of these deficits, the main objective of this renovation strategy is to preserve the building substance in the stock a whole. For the first time, all the school buildings in municipal ownership were surveyed and renovation needs were determined. The objectives to increase energy efficiency measures and lower green gas emissions as well as adapt spatial resources for future educational needs are clearly lacking in this refurbishment approach. However, in the long term perspective, substance renovation approach still preserves school buildings as crucial public resources while allowing several future options - both in future energy efficiency and emission reductions measures, but also with regard to changing educational needs and possible reprogramming.

The portfolio-based approach in Zürich, embedded into a joint long-term strategy, is highly innovative. Equally remarkable is the consideration of building specifics according to their age class as well as construction and material characteristics. Usually, public refurbishment programmes rely on general schemes and measures and disregard the factual heterogeneity of the building stock. Actual instead of calculated energy consumption data would also greatly improve the empirical basis of the study. Critical, however, is the neglect of educational requirements. This portfolio-based approach (still in the stage of a study) can be described as a value enhancing maintenance strategy in reference to classification scheme by König et.al. (9)

Analysis reveals that there are conflicting fields of action in both renovation strategies. Both models disregard current as well as possible future educational requirements and institutional reorganisation. The public school building stock is itself an important element of the educational system. As such it is such a crucial resource for social equity. Therefore, social aspects of sustainability are of central importance in refurbishment planning for educational facilities. In the two municipalities there is a lack of adequate funding for both comprehensive energy based refurbishment as well as major renovation of the whole stock. Municipal budget in Vienna almost completely neglects necessary funding for requires additional space in existing school buildings, such as teachers working areas, different learing zones, facilities for all-day school etc. Because of prolonged financial crisis and decreasing municipal funding, it is not likely, that investments in school building stock will increase in the near future. The solution to this problem can only be the adoption of long term strategies and step-by-step refurbishment and gradual implementation of measures towards institutional modernisation.

Masterplanning

In the USA, in order to obtain funding, five years master plans are required for numerous school districts. Kelley D. Carey, a consultant with extensive experience in master planning for schools, critisizes traditional decision making processes in school planning. According to

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Kelley, building new schools, closing schools but also pupil allocation in US schools can be classified as "disjointed incremental planning". It is often based on insufficient data and no consideration of long term consequences. (10).Instead of random planning decisions, the author proposes to combine three interdependent core elements for master planning: programs (curriculum and pedagogical concept), facilities (spatial resources in the building stock, construction, closures and renovations) and demographics (prognosis and student assignment) which form a triangle for a five year time frame. (10).

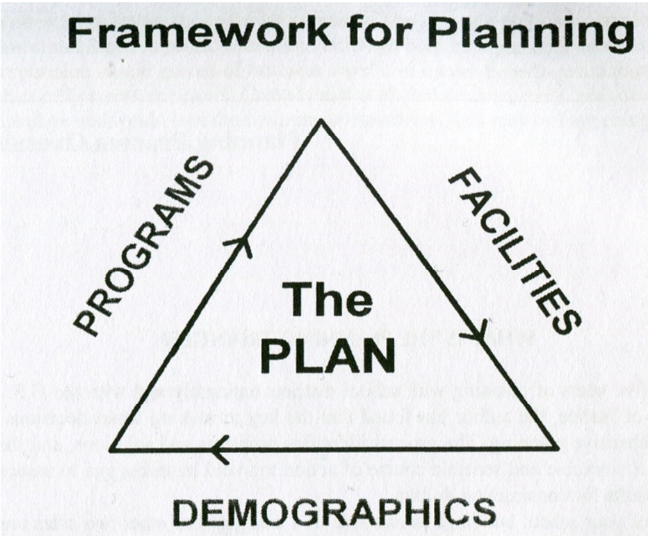

Figure 8: Kelley D. Carey: School District Master Planning, Source (10)

The city of Antwerp is one of the first European cities to adopt a similar master planning strategy for its building stock with ambitious goals in energy saving standards and improvement of learning environments. (11) This pilot project is currently at a stage, where the knowledge base has been put together and the standards for energy efficiency were determined. However, further research on master planning for public building stocks and further pilot projects are needed to fully examine the potential of master planning for sustainability transitions in combination with improvement of institutional organisation.

Only after establishing the basic knowledge base on spatial resources, energy flows, future educational requierements and demographic prognosis, further steps and integrated refurbishment processes are possible. How does sustainability transition route for the buildings stock fit into this framework? First of all - a five year plan is too short. In order to improve resource efficiency of the school building stock, a much longer time perspective 15 to 25 years must be adopted. This long-term, gradual, yet strategic approach is also necessary with regard to limited public budget for education but also in order to resolve the problem of conflicting fields of action in school refurbishment. Master planning is not yet an established instrument for managing and maintaining crucial public resources, such as educational and health facilities as well as administrative buildings, nevertheless, it strategic potential is promising.

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Conclusion

Schools should retain their not-for-profit characteristics. Only by following the goal of social equity and equal opportunity public expenditure in personnel and also building stock is justified. Current refurbishment strategies often favor single fields of action, such as substance preservation or reduction of green gas emissions. Yet in the long term, existing school building stock will only be preserved as a public asset, if its main purposes - education, acquisition of skills and competencies and empowering of young students for active participation in the society is safe guarded. By using long-term master plans for large building stocks, it will be possible to achieve a sound common basis between conflicting future refurbishment requirements from sustainable measures to usage adaptation.

References

1. **Peter, Tracey, Edgerton, Jason D. und Roberts, Lance W.** Welfare regimes and educational inequality: a cross-national exploration. *International Studies in Sociology of Education. Vol.20, No.3.* 2010, S. 241-264.

2. **StatistikAustria.** Statistik Austria. *Bevölkerungsveränderung seit 1981 – Wien.* [Online] 15. 07 2013 a. [Zitat vom: 26. 07 2013.] http://www.statistik.at/web_de/static/bevoelkerungsveraenderung_seit_1981_-_wien_023593.pdf.

3. **OECD.** Education at a glance. [Online] 2001-2009. [Zitat vom: 16. 05 2014.] http://www.oecd.org/education/.

4. **Bellak, Rolf.** Das Wiener Schulsanierungspaket. *Perpektiven.* Heft 3–4 2012, S. 30–32.

5. **Aumann, Anette, Gugerli, Heinrich and Pfäffli, Kathrin.** *Schulen auf dem Weg zur 2000-Watt-Gesellschaft. Schlussbericht Teilprojekt "Szenarien".* Zürich: Stadt Zürich, Amt für Hochbauten, 2011. Studie.

6. **Stadt Zürich.** Hochbaudepartment Stadt Zürich. [Online] 2006. [Zitat vom: 15. 08 2013.] http://www.stadt-zuerich.ch/content/hbd/de/index/hochbau/realisierte_bauten/archive_ab2004/realisiert_2006/Schulhaus_Luchswiesen.html.

7. **Aumann, Anette.** School buildings on the path to the 2000-Watt Society. *nternational Journal of Sustainable Building Technology and Urban Development.* Volume 3, Issue 1 2012, S. 60-67.

8. **Aumann, Anette, Gugerli, Heinrich und Pfäffli, Kathrin.** *Schulen auf dem Weg zur 2000-Watt-Gesellschaft.* Zürich: Stadt Zürich, Amt für Hochbauten, 2011. Schussbericht.

9. **König, Holger, et al.** *Lebenszyklusanalyse in der Gebäudeplanung.* München: Edition Detail, 2009.

ISBN: 978-84-697-1815-5

10. **Carey, Kelley D.** *School District Master Planning. A Practical Guide to Demographics & Facilities Planning.* Lanham, New York, Toronto, Plymouth UK: Rowman & Littlefield Publishers, 2011.

11. **Schoolventcool.** Master Planning for School Building Stock, an Antwerp Experience. *School vent cool.* [Online] 2013. [Zitat vom: 19. 08 2013.] http://www.schoolventcool.eu/sites/default/files/Case%20Study_Master%20Planning%20for%20School%20Building%20Stoch_Antwerp%20Experience.pdf.

12. **StatistikAustria.** Statistik Austria. *Registerbasierte Statistiken, Schnellbericht 2013.* [Online] 07 2013b. [Zitat vom: 26. 07 2013.] http://www.statistik.at/dynamic/wcmsprod/idcplg?IdcService=GET_NATIVE_FILE&dID=146223&dDocName=071439.

13. **Statistik Austria.** Statistik Austria. *Bevölkerungsveränderung seit 1981 – Wien.* [Online] 15. 07 2013 a. [Zitat vom: 26. 07 2013.] http://www.statistik.at/web_de/static/bevoelkerungsveraenderung_seit_1981_-_wien_023593.pdf.

14. **StatistikAustria.** Statistik Austria. *Pressemitteilung: 10.362-215/12.* [Online] 09. 10 2012. [Zitat vom: 26. 07 2013.] http://www.statistik.at/dynamic/wcmsprod/idcplg?IdcService=GET_PDF_FILE&dDocName=067547.

15. **Fawcett, William, et al.** Flexible strategies for long-term sustainability under uncertainty. *Building Research & Information.* 40:5 2012, S. 545-557.

16. **Zürich, Stadt.** *Spezialinventar Schulen.* Zürich: Stadt Zürich, 2008. Studie.

17. **Stadt Zürich.** Hochbaudepartement Stadt Zürich. [Online] 2006. [Zitat vom: 15. 08 2013.] http://www.stadt-zuerich.ch/content/hbd/de/index/hochbau/realisierte_bauten/archive_ab2004/realisiert_2006/Schulhaus_Luchswiesen.html.

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Session 28:

Where should energy renovation reach up to? (II)

Chairperson:

Lützkendorf, Thomas

Head of the Chair of Sustainable Management of Housing and Real Estate Department of Economic and business Engineering at Karlsruhe Institute of Technology (KIT)

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Thermal Rehabilitation in old residential buildings

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Abstract: *Buildings are responsible for 39% of global energy consumption of the planet and the release of 38% of the carbon dioxide. Currently, the majority of the energy production is provided by non-renewable resources with the associated impacts on the world's climate change. It is crucial to find methods to reduce Greenhouse Gas (GHG) and CO2 emissions by improving the efficiency as well as by improving the energy performance of building constructive solutions.*

Due to unsuitable conditions of old buildings in terms of energy consumption and the necessity of its rehabilitation namely in therms of its thermal insulation, this paper describes different material for walls insulation rehabilitation and analyzes the amount of environmental impacts and cost benefits of each one by SimaPro software based on the ISO 14044 standard series. An old residential building in Coimbra's city center was selected as case study.

Key words; Thermal insulation material, Environmental impact, Life cycle assessment, Building rehabilitation.

Introduction

Climate change is one of the most serious environmental threats that the actual world faces. Building sector is one of the keys for the low-cost climate mitigation worldwide and it is in the center of European Union policies for energy efficiency [1, 2]. This sector is the second largest global carbon dioxide emitter after manufacturing industry, representing approximately one-third of the global total emission [3]. Rehabilitation of existing buildings has the opportunity not only to extend the useful life of the existing building stock, but also it offers the opportunity to improve the reduction of environmental impacts by the application of lowering raw materials consumption [4]. Sustainability of the built environment will depend on the demand for a reduction of natural resource consumption and the reduction of the impact of buildings for climate change. Rehabilitation is considered to be an effective strategy to improve the sustainability of existing buildings [5, 6] and reduce the climate change impacts on the built environment [6]. Rehabilitation of existing buildings provides many advantages, namely the maintenance of historical and architectural integrity, the revitalization of urban areas and avoids the negative environmental impacts and the unnecessary consumption of more materials and energy [7]. Rehabilitation can create valuable community resources from unproductive property and substantially reduce construction costs

[8]. In the industrialized European countries with the old constructions and infrastructure stocks the research interest changed to the understanding of the composition and the dynamic behavior of the stocks, i.e. to the operation, maintenance and refurbishment. An improvement in the building energy performance can provide a relevant instrument to relieve European Union energy import dependency and thus comply with the Kyoto Protocol by reducing CO2 emissions [3]. Since the energy use in building sector represents a relevant part of the total energy use and greenhouse gas emissions in the world there is a demand to improve the energy efficiency of buildings [9]. Nowadays, the use of thermal insulation materials plays an important role in the improvement of the building's energetic behavior [10].

The envelope is a relevant part of a building in which external walls plays an important role. The external walls influence the envelope's thermal and environmental performance due to its significant weight in the envelope's initial embodied energy, life cycle energy consumption, life cycle cost and user comfort. Concerning the overall environmental impacts of a building over a 50 years life cycle, walls can represent up to 15% of those impacts [11]. The environmental impacts of an external wall solution depend on the performance of the materials used, specifically the thermal insulation materials, including its initial embodied energy, its thermal properties and its relative position in the wall [11]. Consequently, thermal insulation materials are those that more contribute to save energy used for heating and cooling buildings, improving the building's energy performance [12].

The installation of thermal insulation materials depends on the type of structure, the type of insulation material used and its placement in the structure. Regarding walls thermal insulation can be placed on the outside, on the inside or in between the walls (sandwich or cavity wall). In this research the environmental impact of insulating material in a cavity wall (with inside location of insulation material in wall) is considered. The thermal insulation materials are classified depending on their chemical and physical nature. Insulation materials can be grouped in 3 families: the mineral/inorganic fibrous materials, insulation materials derived from oil and the organic natural [13, 10]. Regarding this last group, agglomerates of expanded cork can be highlighted since Portugal is the major producer and exporter in the world.

The aim of this study was to evaluate the potential environmental impacts of traditional thermal insulation materials used in the rehabilitation of external walls, by life sycle assessment (LCA) method. Thus, the insulation materials selected were Extruded Polystyrene (XPS), Expanded Polystyrene (EPS), Stone Wool (SW) and Agglomerate of Expanded Cork (ICB) as they are the most used materials in building's rehabilitation in Portugual.

Research Methodology

LCA is a methodology for evaluating environmental aspects associated with a product over its life cycle from production, use and disposal. In this study the scope of the LCA is applied to the insulation material of an external wall in a single-family house. The goal of the current LCA study is to take out an environmental profile of different thermal insulation materials. Therefore, the primary objective of the paper is to determine and evaluate individually the

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environmental impacts of four traditional thermal insulation materials used in wall, based on a LCA approach. The secondary aim of the research is to compare these thermal insulation materials in terms of its economic performance and the relation between their cost and global warming potential (GWP). In order to analyze the environmental impact of the different thermal insulation materials in the rehabilitation, use and maintenance phases of the building, firstly, a model of a rehabilitated wall (cavity wall) with thermal insulation material was chosen. The structure of the wall is based on the vernacular architecture of the area of the case study and after that the performed model was analyzed by the SimaPro Software to study its environmental impact.

System Boundary and Functional Unit

The scope of an LCA should specify the functional characteristics of the LCA study. Hence, the scope definition should consider and describe such items as functional unit, system boundaries, data quality requirements and comparison between systems.The “Functional Unit” (F.U) is a reference parameter that describes the primary function of a product (or service) in order to characterize the product’s performance while executing its function. [14] The functional unit defines the quantity of this function that must be considered in the planned LCA. Thus, the functional unit needs to be consistent with the goal and scope of the study, as well as be clearly defined and quantifiable [15].

The system boundary is the interface between the functional unit and the environment. The system boundary of this work, (Figure 1), includes the inputs and outputs of energy and material from the rehabilitation of the wall, use - maintenance, and disposal. Transporting materials to and from the site of the intervention is also included. Maintenance consists of the repair and replacement of materials that are degraded. But in this paper just the environmental impact of the rehabilitaion of wall with different thermal insulation material in rehabilitation, use and maintenance phases will be studied (Figure 1).

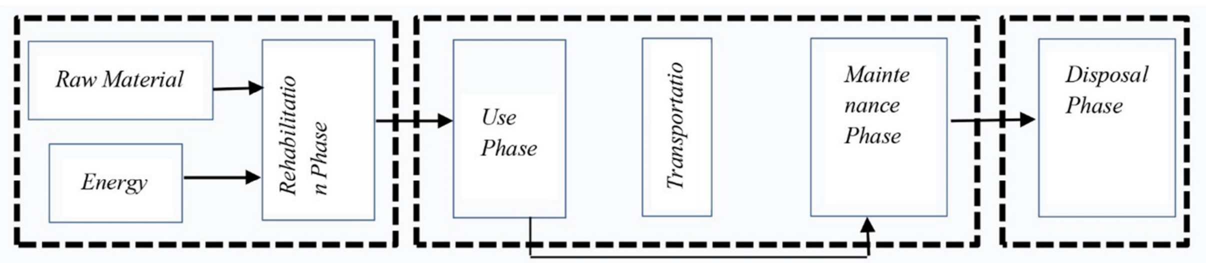

Figure 1: The system boundry of research.

To evaluate the object of the investigation by the LCA methodology, the functional unit of the studies was a square meter ($1m^2$) of the wall with insulation material in the area of a service life with period of 50 years lifespan.

Case Study

The selected house to study is a single family house in the city center of Coimbra, Portugal with 228 square meters of living space. The plan of selected building is presented in below (Figure 2).

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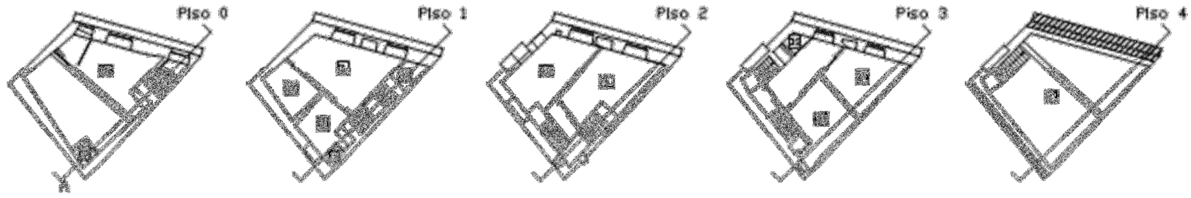

Figure 2: The plans of case study, located in the city center of Coimbra [16].

Discussion

After the inventory phase the collected data were inserted in SimaPro software and assigned to relevant impact categories bye CML2 baseline 2000 (a method to assess the environmental impact categories in Simapro). The environmental indicators which provide a measure of potential environmental impacts have been determined by assigning inputs from the inventory to each impact category (classification) (Table 1).

Imapct Category	***Category Indicator***
Abiotic Depletion	*Abiotic Depletion Potential (ADP)*
Acidification	*Acidification Potential (AP)*
Eutrophication	*Eutrophication Potential (EP)*
Golabal Warming	*Golabal Warming Potential (GWP)*
Ozone Layer Depletion	*Ozone Depletion Potential (ODP)*
Photochemical Oxidation	*Photochemical Ozone Creation Potential (POCP)*

Table 1: Category indacators adapted from CML 2000.

The impact categories and category indicators are defined through the CML2 baseline 2000, impact assessment method. To distinguish the environmental impacts of these different insulation materials in a specific wall the results are presented in following figures and tables. The obtained results from the analysis of the application of different thermal insulation materials in a wall by SimaPro are summarized in Table 2 where it can be seen that each thermal insulation material have different reaction in each category. What is interesting in this data is that, XPS has lowest environmental impact in ADP, EP and ODP but in the category of GWP, which is the aim of this paper, it has one of the highest percent of environmental impact. Another interesting observation is that EPS and ICB have a good competition together on the decay of environmental impact. As Table 2 shows, there is a significant difference in the EP category between these two kinds of materials.

	XPS	***EPS***	***ICB***	***SW***
Abiotic Depletion	*0.022*	*0.091*	*0.068*	*0.092*
Acidification	*0.036*	*0.024*	*0.031*	*0.081*
Eutrophication	*7.69E-05*	*5.94E-05*	*0.011*	*0.017*
Golabal Warming (GWP100)	*2.04*	*1.03*	*0.678*	*3.86*
Ozone Layer Depletion (ODP)	*1.68E-08*	*4.27E-07*	*7.18E-07*	*4.38E-07*
Photochemical Oxidation	*1.74E-05*	*3.4E-05*	*3.59E-04*	*4.29E-04*

Table 2: The environmental impact of four thermal insulation materials.

To distinguish the existing difference of the environmental impact of insulation materials in the wall the table above was summarized in the figure below.

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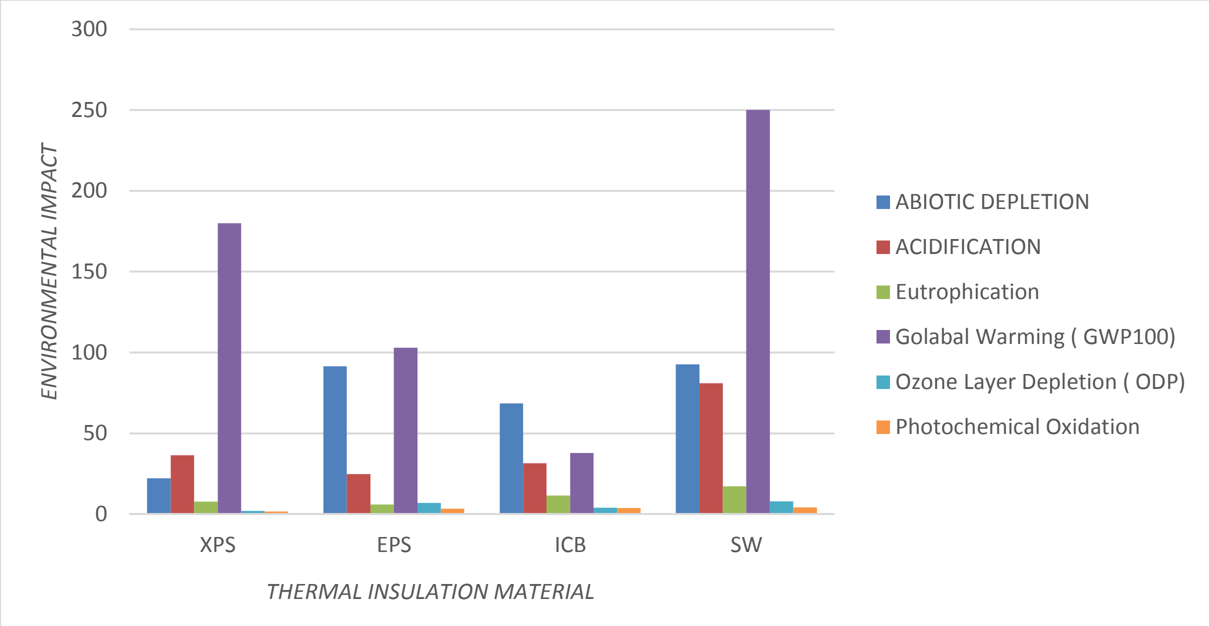

Figure 3: The environmental impacts of considered thermal insulation material.

It is evident from this table that the highest environmental impact of the thermal insulation materials analyzed is referred to their global warming potential and its effect is not comparable with POCP or and ODP. Based on the strong evidence of the obtained statistical results (Figure 3) the percent of global warming category in these insulation materials has high fluctuation while the impact percent of other categories have a slow fluctuation. The figure below illustrates these fluctuations of environmental impacts in all materials.

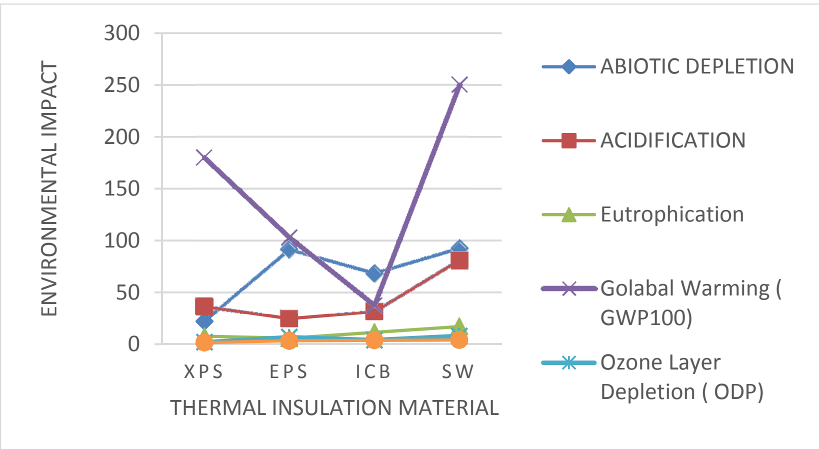

Figure 4: The difference of environmental impacts of considered thermal insulation materials.

In order to evaluate the total environmental impacts of all thermal insulation materials, it is apparent that the SW has the worst behaviour and the ICB and EPS have the best ones as we can see in Figure 5.

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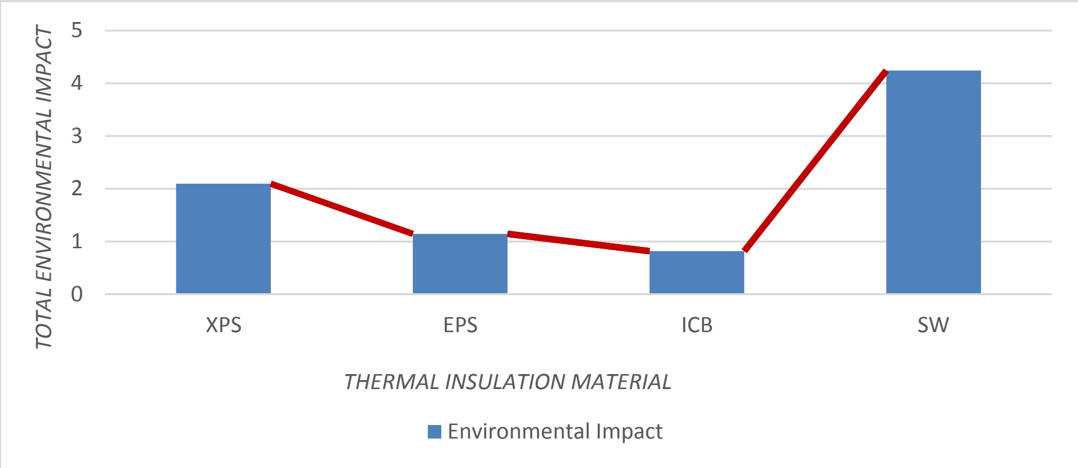

Figure 5: The condition of the environmental impacts of considered thermal insulation materials.

Economic Performance of Thermal Insulation Materials

Since the aim of this research is the analyse of the environmental impacts and the cost of different thermal insulation materials, in following and based on the existing prices of the thermal insulation materials, a economic study was performed in order to compare the insulation materials' cost and how the cost varies with its thickness. The amount of global warming of each material in different thickness is also analyzed. The economic cost of a thermal insulation material (C Insulation) of an external building wall per 1m^2 is associated with:

C Insulation = C Thickness + C Installation

Where; C Thickness is the cost of 1m^2 of a thermal insulation material for a given thickness and C Installation is the cost of its application. The cost of the insulation material was calculated trough the cost of insulation material per F.U and similar procedure was performed to GWP. Table 3 present the cost of insulation material and GWP category.

Material	***Thickness***	***λ (w/mk)***	***Cost(€/F.U)***	***GWP(kgco$_2$/F.U)***
XPS	*0.03*	*0.34*	*7.58*	*2.04*
	0.04	*0.35*	*9.65*	*2.17*
EPS	*0.02*	*0.36*	*3.71*	*1.030*
	0.025	*0.36*	*3.74*	*1.030*
	0.03	*0.36*	*3.91*	*1.035*
	0.04	*0.36*	*4.40*	*1.067*
	0.06	*0.37*	*5.69*	*1.12*
ICB	*0.02*	*0.039*	*6.24*	*0.678*
	0.025	*0.039*	*6.53*	*0.679*
	0.04	*0.40*	*9.24*	*0.79*
SW	*0.02*	*0.34*	*4.71*	*3.86*
	0.03	*0.35*	*5.70*	*3.89*
	0.04	*0.36*	*6.69*	*3.95*

Table 3: The cost of insulation material per function unit and thier GWP.

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Final Results and Discussion

This study sets out with the intent of assessing the amount of environmental impact of different materials. As shown in table 3 EPS and ICB are good options in therms of environmental impact. EPS has the lowest contribution to four impact categories: ODP, AP, EP and POCP. Regarding to GWP impact category, first ranking belongs to ICB based on the goal of this paper which is the low environmental impact with special focus on GWP.

XPS insulation materials have, in general, low contributions towards different impact categories in comparison with their competitors. They have the lowest contribution to ADP and ODP. In fact, XPS could also be the third best option if the decision was based on midpoint results. SW presents the worst results for GWP.

The second objective of this study was to perform a cost analysis of thermal insulation material per F.U. So, it is interesting to note that the results indicate that the cheapest insulation material per F.U is EPS corresponding to the second lowest contribution to GWP. In general when the thickness of EPS increases the EPS's cost per F.U is also increase. Surprisingly, no differences were found in EPS's contribution to GWP and it is constant for thicknesses 0.02 m and 0.025 m. However, for other thickness contribution of EPS to GWP increases. Hence, if the option is EPS, the best choice in terms of thickness is 0.030 m because it has the third lowest cost per F.U and the second rank for GWP.

ICB contributes the lowest to GWP but its cost per F.U is high. If ICB's thickness increases, the cost per F.U is also increase. Therefore, if ICB is chosen as insulation material, the best option in terms of thickness is 0.025 m because it is cheaper (per F.U) than 0.04 m and its cost difference is too few with thickness of 0.02m while its thermal resistance is better than 0.02m and also it has the best environmental performance concerning the GWP category.

Conclusion

As it is explained, the building sector is responsible for a large consumption of energy and CO_2 emissions. In order to contribute to solve this problem, insulation materials prove to be a good technology to reduce energy consumption and therefore increase sustainability in buildings. Despite the vast insulation solutions available, this work is focused on the most common thermal insulation materials available in the Portuguese market. Through LCA methodology the environmental impacts of these thermal insulation materials are evaluated and determined. The purpose of the current study was undertaken to determine the environmental impacts of four conventional insulation materials used in Portugal according to six environmental parameters and also to evaluate the cost benefit of material based on the their impacts categories to select best thermal insulation material to rehabilitate a wall in old residential buildings. The most important findings to emerge from this study are revealed next:

1- ICB has a low contribution to different impact categories, namely GWP. In fact, ICB only has a 1% share in the ADP category, which means that the use and maintenance of the ICB require low consumption of fossil fuels. Nevertheless, ICB has a significant weight on EP and also its GWP is lowest environmental contributions between these four materials. As a result, ICB as the best material for thermal insultion of wall with low environmental impacts can be recommended

2-It is concluded that EPS has a very low contribution to all impact categories after ICB and also has a good cost to use in buildings. So, in economic point of view, EPS could be best thermal insulation material.

3-XPS has a relatively low contribution to all impact categories. The majority of the environmental impacts are generated in the AP and GWP.

4-SW's contribution to various impact categories is very high, namely to ADP and GWP. So, based on the LCA studies, SW shows a bad environmental performance towards relevant impact categories.

The last outcomes were calculated according to these different cases, ICB has the best environmental performance based on the aim of research followed by EPS. SW presents the worst single score results. The conclusions of the economic study are that EPS and ICB are the cheapest and the most expensive materials per m^2 respectively. Regarding the results of the economic performance per F.U. mapped with GWP category it is concluded that EPS has the best results because it has the lowest price per F.U and a low contribution to GWP.

Generally this research tried to find the best thermal insulation material based on their environmental impacts and its costs to rehabilitate walls of old residential buildings in city center of Coimbra. The results of this study indicated that EPS and ICB are the best materials based on different points of view (environmental performance of economic performance) and these information can be used to develop targeted interventions aimed to do rehabilitation in city center of Coimbra.

In this work it was just assumed that the insulation materials are placed inside of external walls (cavity wall) but sometimes this is not the best solution. Since this issue is an extra and important subject it must be investigate in future works.

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Refrences

[1] IEA (International Energy Agency). (2006) Energy Technology Perspectives. Paris, OECD/IEA press.

[2] Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller. (2007a) Climate Change 2007: The physical science basis (Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change). Cambridge, United Kingdom and New York, NY, USA. Cambridge University Press.

[3] Poel, B., G. Cruchten, and C. Balaras. (2007) Energy performance assessment of existing dwellings. Energy and Buildings, 39 (4): 393-403, doi:10.1016/j.enbuild.2006.08.008.

[4] Douglas, J. (2002) Building Adaptation. Butterworth-Heinemann, Woburn, United Kingdom. Cambridge University Press.

[5] Kohler, N. (1999) The relevance of Green Building Challenge: an observer's Perspective. Building Research and Information, 27 (4/5):309-320, doi: 10.1080/096132199369426.

[6] Latham, D. (2000) Creative Re-use of Buildings. United Kingdom. Donhead Publishing Company.

[7] Rovers, R. (2004) Existing buildings, a hidden resource, ready for mining. OECD/IEA Joint Workshop on sustainable Building: Towards Sustainable Use of Building. Paris. OECD press.

[8] Stern, N. (2006) The Economics of Climate Change: The Stern Review. United Kingdom. Cambridge University Press.

[9] Jelle, B. (2011) Traditional, state-of-the-art and future thermal building insulation materials and solutions-Properties, requirements and possibilities. Energy and Buildings, 43 (10): 2549-2563, doi: 10.1016/j.enbuild.2011.05.015.

[10] Papadopoulos, A. (2005) State of the art in thermal insulation materials and aims for future developments. Energy and Buildings, 37 (1): 77-86, doi: 10.1016/j.enbuild.2004.05.006.

[11] Bingel, P., A. Bown, and J. Sturges. (2006) Sustainability of UK masonry in relation to current assessment tools, Paper presented at the 7th International Masonry Conference. London. United Kingdom: CD-ROM, 6 p.

[12] Al-Homoud, M. (2005) Performance characteristics and practical applications of common building thermal insulation materials. Building and Environment, 40 (3): 353-366, doi: 10.1016/j.buildenv.2004.05.013.

[13] Kotaji, J., and O. Loebel. (2010) Sustainability of polyurethane thermal insulation - performance assessment at building and building component level, Paper presented at the Central European Sustainable Building Conference. Prague. Czech Republic.

[14] ISO 14040. (2006) Environmental management - Life cycle assessment - Principles and framework. International Organization for Standardization.

[15] Ardente, F., M. Beccali, M. Cellura, and M. Mistretta. (2008) Building energy performance: A LCA case study of kenaf- fibers insulation board. Energy and Buildings, 40 (1): 1-10, doi: 10.1016/j.enbuild.2006.12.009.

ISBN: 978-84-697-1815-5

[16] Romeu da Silva, V. (2008) Estratégias e metodologias para intervenções de reabilitação urbana Avaliação da vulnerabilidade e do risco sísmico do edificado da Baixa de Coimbra (in portuguese). PhD Dissertation in Civil Engineering, University of Aveiro. Portugal.

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Towards Effective Energy Efficient Rehabilitation of Building Envelopes

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Abstract: *The fight against climate change will increasingly include retrofitting of existing buildings in order to improve their energy efficiency. These improvements must be based on reducing the energy demand. Increasing the performance of the building envelope will be essential. To do this effectively one must know the weak points in existing systems, the possible levels of intervention, and where to invest in order to achieve the best results. To address this need, a procedure for effective rehabilitation of the building envelope in relation to the thermal behaviour is presented. The procedure establishes three building typologies that represent the target population of buildings with energy deficiencies, characterizes construction of the building envelope which are pertinent to energy performance (the facades, roofs, windows, etc.), and characterizes suitable retrofitting measures. Results are presented in the form of matrices, which is intended to serve as a tool for making decisions that enable efficient interventions.*

Key words*: energy consumption, energy retrofit, building envelope; method of evaluation, monitoring, simulation, decision matrixes, risk levels*

1. Introduction

The energy performance objectives established by the European Union for 2020 [1] have resulted in a target of attaining a net goal of 'nearly-zero emissions buildings' (NZEB) across all of the building stock: new and existing. To achieve this goal, rehabilitation of existing buildings will be required. In addition, there is now also the challenge of energy poverty: families spending more than 10% of their total annual incomes to pay their home energy bill, and/or being unable to maintain adequate comfort. Many of these energy impoverished families live in older buildings with deficient thermal envelopes: a factor that enhances thermal transmission losses and uncomfortable environments. In these cases, a cost-effective approach for energy rehabilitation should be a priority. The European Economic and Social Committee (CESE) agrees, having proposed that energy poverty be used as a basis to establish energy policy, and confirming that improving building energy efficiency is an essential component [2].

In Spain, about 46% of the existing housing stock consists of multi-story concrete or masonry buildings, constructed between 1940 and 1980. Much of this building stock is used for social housing. In addition, in 2014, it is estimated that more than 15% of households could be affected by energy poverty [3].

This combination of a very large number of old and likely energy-inefficient buildings, housing large numbers of energy-poor populations, makes an ideal sample for development of

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a cost-effective approach for energy rehabilitation. This building population group is therefore the focus of research being carried out by the group SAVIArquitectura, from Universidad de Navarra, Pamplona, Spain, in collaboration with Worcester Polytechnic Institute (WPI) in the USA. Supported by the Spanish Ministry of Economy, the objective of the research, "Performance Buildings Envelope Rehabilitation Protocol (prestaRener)," is the development of a performance-based design approach for identifying cost-effective strategies for rehabilitating the energy performance of existing buildings envelopes, taking into account building attributes and social-economic factors.

To date, a methodology has been developed which identifies key energy performance attributes of the exisiting building stock in Pamplona, Spain, identifies and assesses energy retrofit options using computational analysis and actual building performance data, and provides a pathway to decision-making for retrofit of social housing, considering energy poverty and related demographics. This paper overviews the performance assessment methodology, using a case study to illustrate the range of energy performance increases which can be achieved. Future papers will present the cost-effectiveness analysis and strategies for developing and prioritizing policy decisions based on energy poverty and related socio-economic concerns.

2. Methodology

The methodology is overviewed in Figure 1. In brief, it begins by defining a set of three residential building typologies which represent the majority of the target building stock. It then breaks down the specific components of the building envelop (facades, roofs, windows, etc.) which contribute to energy loss. Various strategies for mitigating the losses are then identified, and combinations of options are assessed via computational modeling. Data on actual building energy performance, obtained through measurements within buildings in Pamplona, are used as a baseline and to help identify those parameters which have the biggest influence on energy consumption. Cost-effectivess of options is then considered. Due to the complexity of the methodology, only a small fraction can be described here. This includes an overview of the building typologies, an overview of the mitigation options, and a comparison of the relative performance of the mitigation options based on data and computational modeling.

3. Representative building typologies

Given the focus on (a) existing buildings and (b) energy poverty, typologies were identified based on social housing constructed between 1940 and 1980, excluding single family houses. Three typologies have been defined: T1, Linear Block, T2, H-Block, and T3, Tower. These are illustrated in Figures 2-4 below.

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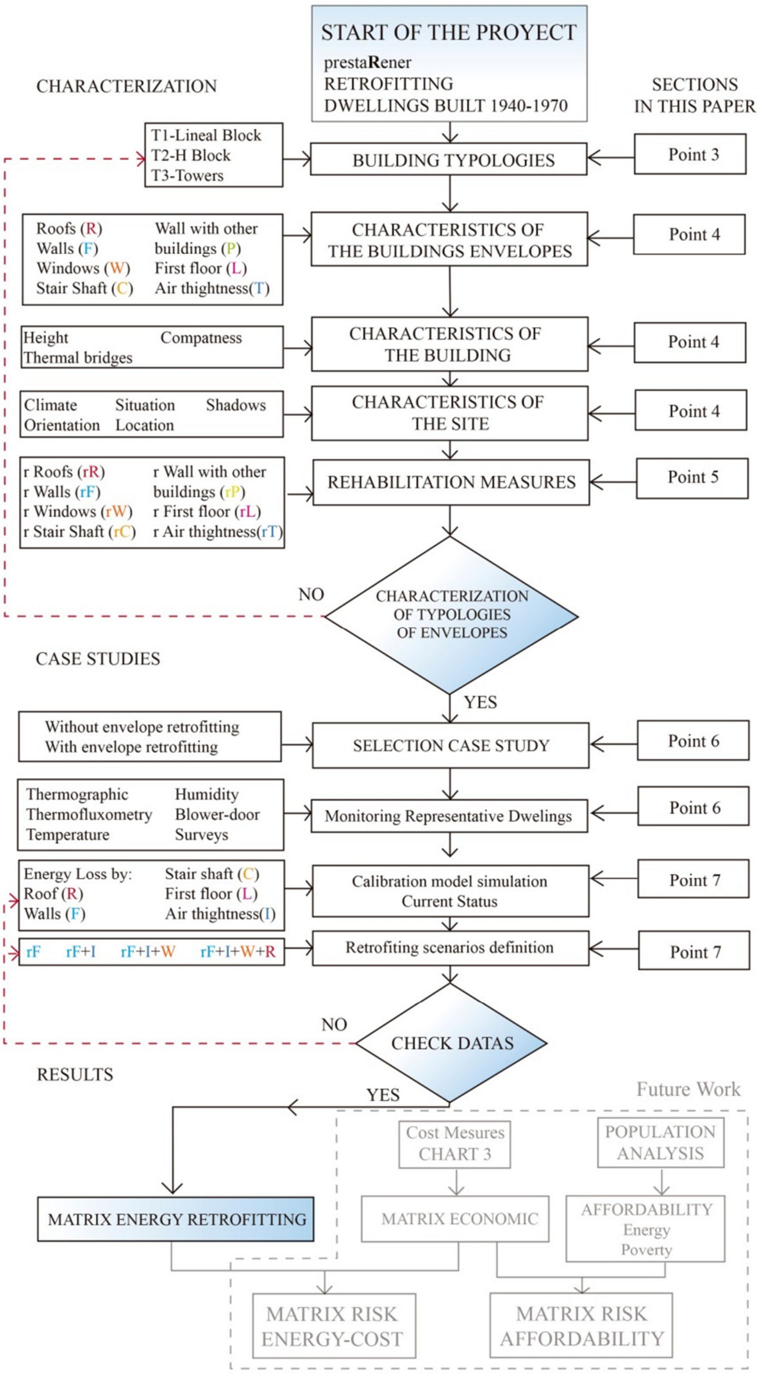

Fig. 1 Methdology

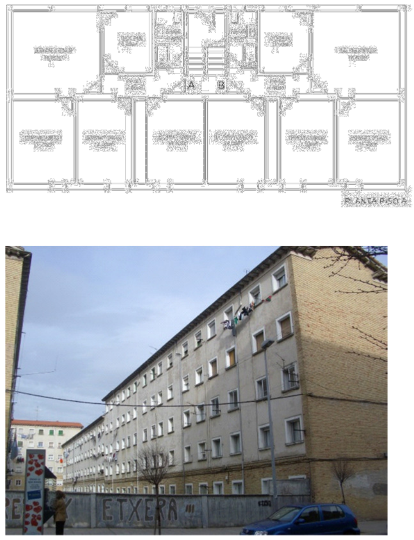

Fig. 2 Linear Typology

Fig. 3 H-Typology

Fig. 4 Tower Typology

Each building typology has two sub-typologies, based primarily on construction / layout differences based on timeframe of construction, which have an influence of energy performance. The differences are summarized in Table 1 below.

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Table 1. Definition of Typologies

Type Description	Year of construction	Height	dwellings per floor	M2 dwelling	Orientation	Façade	Roof	GF
T1 Linear Block (Fig. 2)								
T1.1 No grouped	1940-1950	≤PB+4	2	45-60	Double 180º	F2	R2	L4
T1.2 Grouped in quarter	1950-1960	≤PB+4	2	65-80	Double 180º	F3	R2	L3
T2 Block in "H" con agrupación lineal (Fig. 3)								
T2.1 h≤PB+4	1960-1970	≤PB+4	4	60-70	Double * 180º	F1	R2	L2
T2.2 h>PB+4	1970-1980	>PB+4	4	80	Double* 180º	F3	R2	L2
T3 Tower (Fig 4)								
T3.1 In H with lateral courtyard	1960-1970	>PB+8	4	60-70	Double 180º	F4	R1	L3
T3.2 Without courtyard	1970-1980	>PB+8	4	<90	Double 90º	F4	R1	L1/ L3
(*) One façade to street, the other a small courtyard								

4. Definition of building envelope characteristics

To obtain reliable and consistent results, it is essential to have a clear characterization of the major components of the building envelope which influence thermal performance for the defined building typologies. The major characteristics are shown in Table 2.

Table 2 – Building characteristics

Façade, F	F1 - Façade of one wythe, solid brick, 24 cm, face view or to cover	F2 - Façade of hollowbricks, LHD 24 cm	F3 - Façade of cavity Wall, one sheet brick face view and another hollowbrick	F4 - Façade of cavity Wall, double sheet hollowbricks
Roof, R	R1 - Flat Roof	R2 - Pitched Roof, unheated	R3 - Pitched Roof, heated	
Windows, W	W1 - Wood Frame + single glass	W2 - Other material Frame + single glass		
Ground Floor, L	L1 – Open 100%	L2 – Enclosed unheated	L3 – Enclosed heated local	L4 - Enclosed heated house

Charactersitics associated with separations between walls and stair shafts (C) and walls within other dwellings or buildings (P) were also included in the analysis, but were identified as not being significant and are not included in this paper. In addition, there are several attributes which influence performance, including building height, area ratios (e.g., envelope area/total volume, glass area/wall area, roof area/envelope area), thermal bridges, and air infiltration, which are included in analysis but not detailed here. In addition, future iterations will include site characteristics and influences, including climate zone, building orientation and situation / impacts associated with the site (shadow from other buildings) as well.

5. Definition of rehabilitation measures

A wide range of systems that exist in the market have been analyzed for their feasibility and fit with respect to mitigation thermal losses (energy demand). In addition, solutions for point-

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type loss mechanisms (e.g., thermal bridges, air infiltrations, etc.) have been investigated. The rehabilitation measures identified from these analyses are presented in Table 3.

Table 3 – Rehabilitation measures

Façade, rF	Exterior insulation (4,8,12 cm)	Interior insulation (4, 8, 12 cm)	Insulation in cavity (4, 8 cm)
Roof, rR	Exterior insulation (8,10,14 cm)	Interior insulation (8,10,14 cm)	Insulation in cavity (8,10,14 cm)
Windows, rW	Double glass 4.12.6	Double glazed low emissivity 4.12.6 Lo	Double window outside the existing
Stair Shaft, rC	Insulation (2,4 y 6 cm)	Walls w/other buildings, rP	Insulation (2,4 y 6 cm)
First Floor separation, rL	Exterior insulation (8,10 y 14 cm),		
*Note: the ‘r’ in front indicates a rehabilitation option, e.g., rF is rehabilitated Façade			

6. Data collection from representative dwellings

To verify typologies and envelope components and to collect in-situ data on energy performance, a set of representative buildings from Pamplona and Navarra, reflecting each typology, were identified and selected for case studies. Data collection and analysis related to thermal losses / energy performance included: evaluation of thermal transmittance of opaque elements (such as roofs, façades…), which was evaluated theoretically with the CTE-HE1 procedures [4] and in actuality using thermofluxometry [5], evaluation of thermal bridge losses, which was done qualitatively through thermographic inspection [6], and air infiltration testing to measure tightness of the building, using blower door apparatus [7].

To obtain a range of performance data, various building configurations and conditions were assessed. Some of the case study dwellings had original windows and others had new ones. Both sets of results are used as data in the energy performance simulations. The blower door test coupled with the thermographic camera allowed us to understand the origin of air infiltration points, such as around windows, blind box, joints, etc. In addition, data to assess interior comfort were also collected, including exterior and interior temperature and humidity data in different parts of the dwellings. This allows the analysis of the distribution and uniformity of temperature and humidity as another means to detect inadequate behaviour, such as lack of air movement (ventilation) which could derive in the development of negative impacts (e.g., condensation). Various measurements were also taken of the façades to provide data on the uniformity of the insulation.

A range of data collection locations were selected in order to assess energy performance for a different building component relationships, including dwelling on intermediate floors, dwellings under the roof, dwellings contact with the ground floor or the ground, dwellings in a corner, etc. To enhance the information, surveys were used to collect data from occupants on use of heating, cooling and ventilation systems and habits, and well as socioeconomic aspects (for future assessment relative to energy poverty decision making). The obtained results are important as they reflect real input for the simulations, not default values.

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7. Simulation of scenarios and energy rehabilitation interventions

The objective of this task was to simulate, with the use of software tools (in this case, Design Builder), the performance of the envelope using real data obtained from testing, adjusting the simulation profile to the real performance. This provides a baseline for then assessing mitigation options. In addition, the heating demand is assessed for different parts of the envelope to identify ones with the biggest impact and which therefore need to be improved. For example, analysis shows that in type T1 buildings, the heat losses are due to: opaque façades (26%), windows (15%), air infiltration (29%), roofs (7%), slab with ground floor (10%), walls with stair shaft (5%) and with other buildings (8%). Given this baseline, different levels of intervention were then simulated, calculating the energy savings and the cost of every measure considered (Table 3). Measures considered included rehabilitation of the façade (rF), improvement of air infiltration (rI), rehabilitation of the roof (rR), rehabilitation windows (rW), rehabilitation walls with stair shaft (rC), rehabilitation of the walls with other buildings (rP), rehabilitation of the separation with ground floor (rL), and various different combinations (rF+I, rW+I, rF+W+I, rF+W+I+R,...). Data for temperatures, internal charges and ventilation criteria for the simulation are taken from CTE-HE.

8. Results

Results of the analyses are presented in the form of matrices, which illustrated the most influential parameters for reducing energy demand (thermal losses). Matrices have been selected as they provide way to quickly

Spatial Quality in Building Performance Assessment Tools

The case of Dwelling Renovation for Energy Efficiency

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Abstract: *The contribution of this paper is to analyse the availability of spatial quality assessment in two major building performance assessment tools that are used in Europe considering dwelling renovation: the Building Research Establishment Environmental Assessment Method UK 2008 (BREEAM UK 2008) and the Sustainable Buildings Tool (SBTool 2012). Spatial quality contributes to people's well-being and quality of life and therefore its inclusion in renovation processes gives arguments that may increase stakeholders' receptiveness to and investments in energy-efficiency renovation. This paper reveals part of the gap and the conflict between technical and non-technical dimensions in the tools, and suggests opportunities for improvement in terms of validity, reliability, sensitivity and specificity of the spatial quality assessment. Due to their relevance to (1) and wide-ranging cover of the building process, tools open up an opportunity to implement spatial quality assessment in dwelling renovation. Including more and better spatial quality*

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indicators in the tools can contribute to raising awareness of the importance of this issue among design professionals and decision makers, and provide additional incentives for energy efficiency.

Keywords: spatial quality, building performance assessment tools, BREEAM UK 2008, SBTool 2012, non-technical dimensions, energy renovation of residential buildings

1. Introduction

The two elements under consideration in the study are introduced in this section. The first element is spatial quality and the second element is the assessment of spatial quality available in actual building performance assessment tools used for dwelling renovation. In this section we first summarise the definition of spatial quality (2). Second, we introduce the analysis of building performance assessment tools for spatial quality assessment. We analyse two assessment tools for dwelling renovation: BREEAM (Building Research Establishment Environmental Assessment Methodology) UK 2008 for Major Refurbishment and Multi-residential Use, and SBTool (Sustainable Buildings Tool) (2012). The aim is to find out whether these tools include spatial quality and how effective they are in assessing spatial quality. BREEAM UK 2008 and SBTool (2012) have been selected for this study because of their relevance in the building industry in Europe.

The definition of the term spatial quality results from the literature review, which resulted in diverse approaches to spatial quality on the building scale being found (2). The result of the review of the literature on spatial quality is the setting up of and the definition of four determinants: (I) views, (II) internal spatiality and spatial arrangements, (III) the transition between public and private spaces and (IV) perceived, built and human densities (2).

The main topics of the spatial quality determinant of (I) view are: (a) the view from the inside to the outside of dwellings and from the outside to the inside (visual privacy), (b) distances between public and private domains and (c) view quality. The second determinant of (II) internal spatiality and spatial arrangements consists of the analysis of (a) the articulation between space and its boundaries, and between adjacent spaces, (b) the privacy within the dwelling and (c) light (access of daylight) (2). In (III) the transition between public and private spaces, the main topics for analysis are (a) physical barriers between public and private spaces, (b) outdoor private spaces and (c) the facade composition and permeability. The last spatial quality determinant of (IV) perceived, built and human densities considers (a) block physical boundaries, (b) the height-to-width ratio of internal block spaces and the sense of enclosure and (c) functions in the block, and built and human densities (2).

We found that spatial quality is already indirectly considered by BREEAM UK 2008 and SBTool (2012). Both tools have indicators whose issues of concern are directly related to the spatial quality definition (2), for example the fact that these tools consider the assessment of views and outdoor private spaces. This indicates the actual awareness of the relevance of non-technical dimensions such as spatial quality as well as of the potential for improvement of the tools in order to assess non-technical dimensions.

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Assessment tools are designed to measure performance, and they are not necessarily the best options for guiding and promoting changes in design, despite their current influence in building processes (3). They concentrate on assessing diverse issues through metrics, checklists, scores and ratings. Most of the literature on building performance assessment tools concentrates on the technical character of the tools that indicate a 'preference for clearly measurable outcomes' (4, p. 131). Nevertheless, the inclusion of non-technical dimensions and the influence of the tools on stakeholders are as relevant as technical issues in the promotion of a sustainable building environment. Due to the widespread use of the tools, and the importance and diversity of the categories assessed, they constitute an opportunity to include and promote non-technical dimensions such as spatial quality.

2. Spatial Quality Assessment in Practice

We analysed two building performance assessment tools in the search for a spatial quality-related assessment. The sources considered for the analysis of the tools BREEAM UK 2008 for Major Refurbishment and Multi-residential Use, and SBTool (2012) are the official guidelines, the Excel® sheets and websites. For the purpose of this study BREEAM UK 2008 was calibrated to assess major refurbishment of multi-residential use. The generic version of the SBTool (2012) was calibrated to assess dwelling renovation. We considered the SBTool's maximum scope, which is the full version with all criteria assessable in the tool.

The tools BREEAM 2008 and SBTool (2012) assess the environmental performance of buildings using sets of indicators organised into diverse categories. According to the World Health Organization (WHO) (5), an ideal indicator should have the scientific characteristics of (I) validity (it has to measure what it is possible to measure); (II) reliability (repeated measurements by different observers have to result in similar values for the same indicator); (III) sensitivity (the ability to capture changes); and (IV) specificity (only reflecting changes in a particular situation). Indicators are generic and are only intended for assessment; they consist of a description of data that have no positive or negative values associated with them (6). The context and the aim of the assessment lead to the definition of values for the assessment.

The term spatial quality is not mentioned in the tools BREEAM UK 2008 for Major Refurbishment and Multi-residential Use or SBTool (2012). However, the tools do in fact consider elements of spatial quality (Table 1) (2). The construction industry has been influenced by building performance assessment tools (4). This is because the tools function as guidelines for design teams regarding the dimensions that need to be considered in the construction process. This indicates the potential of the tools to include non-technical dimensions, such as spatial quality, in the construction and design process.

Table 1. Overview of the spatial quality related indicators in the tools BREEAM UK 2008 for Major Refurbishment and Multi-residential Use and SBTool (2012). The indicators are classified according to their relation to the four spatial quality determinants (2).

Assessment Tools →	**BREEAM 2008 Major**	**SBTool (2012)**

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<table>
<tr><th>Spatial Quality Determinants ↓</th><th colspan="2">Refurbishment/ Multi-residential Use</th><th colspan="2"></th></tr>
<tr><td>Views</td><td>Hea[1] 2
View Out</td><td rowspan="2">Hea 1
Daylight</td><td>F1[4] Social Aspects
(Visual Privacy)
F3 Perceptual
(View Out)</td><td rowspan="2">F1 Social Aspects
(Sunlight)
D3[5] Daylight/ Illumination</td></tr>
<tr><td>Internal spatiality and spatial arragements</td><td>*</td><td>*</td></tr>
<tr><td>Transition between public and private spaces</td><td colspan="2">Hea 15 Outdoor Space
Ene[2] 18 Drying Space</td><td colspan="2">F1 Social Aspects (Private Open Space)</td></tr>
<tr><td>Perceived, built and humand densities</td><td colspan="2">LE[3] 1 Land Reuse</td><td colspan="2">A2[6] Urban Design (Efficiency of Land Use)</td></tr>
</table>

*Spatial quality feature not considered by the tool.

[1]Category Health and Well-being (Hea)

[2]Category Energy (Ene)

[3]Category Land Use and Ecology (LE)

[4]Category F Social, Cultural and Perceptual Aspects

[5]Category D Indoor Environmental Quality

[6]Category A Urban Design, Efficiency of Land Use

BREEAM UK 2008 for Major Refurbishment and Multi-residential Use
Views, daylight and outdoor private spaces are the spatial quality related topics considered by BREEAM UK 2008. The assessment associated with the spatial quality determinants of (I) views, (II) internal spatiality and spatial arrangements and (III) the transition between public and private spaces is included in the categories of Health and Well-being (Hea) and Energy (Ene). The issues related to views are Hea 2 View Out and Hea 1 Daylight. Daylight is the only issue related to the spatial quality determinant of internal spatiality and spatial arrangements in BREEAM UK 2008.

Transitions between public and private spaces appear in the issues Hea 15 Outdoor Space and Ene 18 Drying Space. The provision of outdoor amenity space both for private and collective use is recommended in the indicator Hea 15 and Ene 18. However, the provision of outdoor spaces in Ene 18 is only in order to provide space for drying clothes. The spatial quality determinant of (IV) perceived, built and human densities is taken into consideration in the category of Land Use and Ecology, issue LE 1 Land Reuse. However, the issues Hea 1 Daylight, 2 View Out, 15 Outdoor Space and LE 1 Land Reuse are not included in the list of minimum standards that must be attained in order to achieve a BREEAM rating (7). Furthermore, only the issue Hea 1 Daylight is included among the BREEAM credits required for a project to be considered as innovative (7).

SBTool (2012)
Views, visual privacy, daylight and outdoor private spaces are the spatial quality related topics considered by the SBTool (2012). The assessment associated with the spatial quality determinants of (I) views, (II) internal spatiality and spatial arrangements and (III) the

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transition between public and private spaces is included in two categories: (F) Social, Cultural and Perceptual Aspects and (D) Indoor Environmental Quality.

The criteria related to views are F1 Visual Privacy and Sunlight and F3 View Out. Measures to increase visual privacy are recommended in the sub-criterion SBTool F1.3 Visual Privacy. In this sub-criterion F1.3, the indicator consists of the analysis of visual privacy through the number of openings to exterior views and their placement on the facade. In the indicator of the sub-criterion SBTool F1.2 Sunlight, the access of direct sunlight is measured by the percentage of ‘dwelling units whose principal daytime living areas have direct sunlight for at least 2 hours per day’ (8, tool spreadsheet1). The indicator considers the most unfavourable time of the year, 12 noon at the winter solstice. The evaluation relies on the design documentation. The indicator of the sub-criterion SBTool F3.7 Access to Exterior Views from the Interior deals with the view quality, the presence of nature and distances between exterior artefacts and the viewer.

The criterion D3 Daylight and Illumination is both related to views and to internal spatiality and spatial arrangements. The indicator of the sub-criterion SBTool D3.1 Daylighting analyses the appropriate day lighting (daylight factor) in primary occupancy areas on the ground floor of buildings. SBTool D3.1 is the only sub-criterion that is part of the minimum mandatory criteria. Transitions between public and private spaces are considered in the criterion F1 Private Open Space. The indicator of the sub-criterion SBTool F1.4 Private Open Space measures the private and collective outdoor spaces in square meters (m^2). It also considers the percentage of homes ‘that have attractive and usable private outdoor areas’ (8, tool spreadsheet[2]).

Determinant (IV), perceived, built and human densities, is taken into consideration in the category of (A) Site Regeneration and Development, Urban Design and Infrastructure, criterion A2 Urban Design, Efficiency of Land Use. The indicator of sub-criterion A2.1 Land Use measures the built density expressed as the ratio between the gross floor area achieved by the design and the maximum permitted gross floor area on the site (8, tool spreadsheet[3]). All the spatial quality related sub-criteria are active by default in the design and operational phases of the renovation project, except for sub-criterion A2.1 Land Use Efficiency, which is not active in the operational phase. However, none of the spatial quality related sub-criteria are automatically active in the pre-design phase.

3. SBTool (2012) and the Potential for Development of Spatial Quality Assessment

In this section, the sub-criterion SBTool F3.7 Access to Exterior Views from the Interior is presented as an example of the analysis made of the available indicators of SBTool for spatial quality assessment. The analysis also indicates the potential for development of spatial quality assessment in the SBTool.

[1] SBTool Excel® spreadsheet SBT12_A_Generic_Max_3_Dsn_30Oct12
[2] SBTool Excel® spreadsheet SBT12_A_Generic_Max_3_Dsn_30Oct12
[3] SBTool Excel® spreadsheet SBT12_A_Generic_Max_3_Dsn_30Oct12

Indicator evaluation
Name/description: Sub-criterion SBTool F3.7 Access to exterior views from interior

- Definition/description of sub-indicators/units. 'Visual quality of exterior artefacts or natural objects and their distances from the viewer'; this can be measured in meters (m).[4] Sub-criterion F3.7 is not a mandatory in the assessment.
- Principles of classification. 'To assess the quality of exterior views available to an observer located in an interior space of a main occupancy'.[5]
- Assessment. Comparability: The indicator fulfils the requirements of comparability because of the use of scores from -1 to 5. Assessment method: Analysis of the floor plans prepared by the design team only; Applicability: The indicator is applicable to two-dimensional assessment. The assessment is performed in the design phase only.

The indicator does not specify what is meant by quality of exterior views or visual privacy. It bases its assessments on subjective concepts that give space for individual interpretations, such as: 'views are unacceptably ugly', 'visually acceptable', 'features of considerable interest' and 'natural features that are visually attractive'.[6] The indicator does not follow the scientific characteristics of an indicator of validity, reliability, sensibility and specificity (5) because the assessment is based on subjective concepts.

Furthermore, the sub-criterion to which the indicator belongs has a weight of only 0.24% out of 1.7% (criterion weight), the assessment is not considered mandatory, and the scale of the assessment is limited. The weight of 1.7% for the criterion F3 Perceptual is also low for its category, considering its impact on spatial quality. The building is the only object of the assessment, although the configuration of the block in which the building is located influences substantially the visual quality and distances between public and private domains. The status of the indicator indicates the potential for cooperation between SBTool and BREEAM in the development of indicators for assessing exterior views.

The score method offers reliable results for comparability, but the assessment method does not because the scores are given based on subjective assessment, such as views that are 'unacceptably ugly'.[7] The assessment uses only floor plans (two-dimensional), which, considering the complexity of visual quality and visual privacy, indicates the limitation of the assessment. The source of information for the assessment is also limited. The only material considered is that supplied by the design team; site visits done by external people are not mentioned.

4. Conclusion and Further Work

The results of the analysis of BREEAM UK 2008 for Major Refurbishment and Multi-residential Use and SBTool (2012) indicate the deficiency of these tools in assessing spatial

[4] SBTool Excel® spreadsheet SBT12_A_Generic_Max_3_Dsn_30Oct12
[5] SBTool Excel® spreadsheet SBT12_A_Generic_Max_3_Dsn_30Oct12
[6] SBTool Excel® spreadsheet SBT12_A_Generic_Max_3_Dsn_30Oct12
[7] SBTool Excel® spreadsheet SBT12_A_Generic_Max_3_Dsn_30Oct12

quality. First, the study indicates that spatial quality is partially considered by BREEAM UK 2008 and SBTool 2012. Second, it indicates that the spatial quality related indicators available in these tools consist essentially of recommendations rather than sufficiently developed indicators. This is because these indicators do not fulfil the level of development necessary to be considered effective indicators according to the definitions of WHO (5) and ISO21929-1 (6). The most relevant limitation of both tools is the lack of definitions. For example, the indicators related to the access to exterior views in both tools consist of only recommendations about the need for an 'adequate view out' (BREEAM UK Hea 2) or the relevance of 'visual quality' (SBTool F3.7). Neither further direction nor clear assessments and definitions are given. However, SBTool (2012) does include visual privacy, while this is not mentioned in BREEAM UK 2008.

The analysis of BREEAM UK 2008 and SBTool (2012) indicates their large potential for the improvement of validity, specificity, sensitivity and reliability in assessing spatial quality. The results of this paper are the departure point for the development of new indicators and the improvement of existing ones to integrate spatial quality assessment into the renovation of dwellings. SBTool's spatial quality related indicators more often fulfil the requirements of the scientific characteristics of an ideal indicator than indicators of the same category in BREEAM UK 2008. For example, the sub-criteria SBTool F1.2, F1.3, F1.4 and F3.7 have indicators that measure percentages, metres and square metres (validity). That is, repeated measurements by different observers result in similar values of the same indicator (reliability). An indicator that has some kind of measurement can capture changes (sensitivity), because measurements can be taken repetitively, and changes in measurements are particular to a specific situation (specificity). BREEAM UK 2008 considers the spatial quality related assessment throughout the entire building process, whereas SBTool (2012) considers it only at the design and operational stages for dwelling renovation.

This research is connected to the ZenN project Nearly Zero Energy Neighbourhoods funded by the European 7th Framework Programme (grant agreement no: 314363), Work Package 4 Non-Technical Drivers. The ZenN project aims to 'demonstrate the advantages and affordability of energy efficiency renovation, and to create the right context to replicate this experience around Europe' (9). The goal of the WP4 is to support the success of energy-efficiency strategies in dwelling renovation by optimising the synergies between technical and non-technical dimensions, to which spatial quality belongs.

References

[1] Cole, R. J. & Valdebenito, M. (2013). The importation of building environmental certification systems: international usages of BREEAM and LEED. *Building Research & Information*, volume 41, *no. 6:* 662-676, DOI: 10.1080/09613218.2013.802115

[2] Acre, F. & Wyckmans, A. (2014). Spatial quality determinants for building renovation: a methodological approach to the development of spatial quality assessment. *Journal of*

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Sustainable Technology & Urban Development SUSB, DOI:10.1080/2093761X.2014.923793, published online from June 2014, and forthcoming on paper version in September 2014.

[3] Du Plessis, C. (2011). Towards a regenerative paradigm for the built environment. *Building Research & Information*, volume 40, *no. 1*: 7-22.

[4] Schweber, L. (2013). The effect of BREEAM on clients and construction professionals. *Building Research & Information*, volume 41, *no. 2*, 129-145.

[5] World Health Organisation (WHO): http://www.who.int/en/. Accessed in January 2014

[6] International Standard ISO 21929-1, *Sustainability in building construction – Sustainability indicators.* Switzerland: ISO; 2011. http://www.iso.org/iso/home/standards.htm. January 2014

[7] BREEAM UK (2008) BREEAM: http://www.breeam.org/. January 2014

[8] SBTool (2012) iiSBE http://www.iisbe.org/. January 2014

[9] Nearly Zero Energy Neighbourhoods, ZenN (2012). *Seventh Framework Programme Part B, Collaborative Project with Predominant Demonstration Component* (report: project description).

and clearly see the range of effectiveness of different rehabilitation measures for the different building typologies. In future stages of the project, the matrices will be updated to include cost data, providing a good orientation for practitioners to support better and more optimized decisions for cost-effective rehabilitation options. This will also be very useful for public authorities, which aim to establish and finance building rehabilitation policies based on optimizing or prioritizing intervention options based on energy poverty or other such socio-economic drivers.

Table 4 below reflects the percent reduction in energy demand for various thermal performance rehabilitation options for the T1, Linear Block building typology. The matrix shows different combinations of measures (Table 2) for Typology 1 and the impact of the different measures adopted.

Table 4. Matrix of percentage energy reduction for Type 1 buildings by major intervention

ENERGY MATRIX - T1 LINEAR BLOCK - ENERGY RETROFITTING SCENARIOS REDUCTION DEMAND OF ENERGY (%ENERGY SAVING)						
F1/R2/L2 158Kwh/m2/y	Exterior insulation in Facade rFei			Interior insulation in Facade rFii		
	ei12	**ei08**	**ei04**	**ii12**	**ii08**	**ii04**
rF+I+W+R	88.34	85.66	78.85	81.53	75.9	70
rF+I+W	79.19	76.82	70.64	67.27	65.21	60
rF+I	60.37	57.72	51.44	47.41	45.35	40.23
rF	52.5	50	43.5	45	43	34
Significant reduction: >75%			Moderate reduction: 45-60%			
High reduction: 60-75%			Low reduction: <45%			

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Table 5. Matrix of percentage energy reduction for Type 1 buildings by minor intervention

ENERGY MATRIX - T1 LINEAR BLOCK - ENERGY RETROFITTING MEASURES REDUCTION DEMAND OF ENERGY (%ENERGY SAVING)															
T1	rW+I			rW			rR			rL			rC		
	2W	LoE	2G	2W	LoE	2G	14	10	8	14	10	8	6	4	2
Savings*	18.8	18.7	17.6	4.87	4.77	3.83	6.1	5.8	5.5	4.4.	4	3.5	3.3	3	2.25
*Reflects the percent energy savings with differents minor intervention measures. Results show very small contributions by the minor intervention meassures.															

Similar matrices have been developed for all the typologies evaluated. At the present time, the measures are being economically quantified, and as note above, future publications will include the cost-effectiveness aspect in the matrices (or in different matrices, as appropriate). In the next stage of the project, data related to socioeconomic aspects of the population, including age, employment status, family composition, education, etc. are being collected so as to address the energy poverty component for public policy support. This is being accomplished through use of surveys as well as existing official census and related data. This will help importantly inform building rehabilitation decisions in cases of energy poverty.

9. Conclusion

This paper briefly describes the methodology designed for the carrying out of the prestaRener research project on a performance approach for identifying cost-effective strategies for rehabilitating the energy performance of existing buildings envelopes. The methodology has been validated by studying different cases for each of the selected typologies and some results for typology T1.1 are presented. In this case, key contributors to heat loss, and therefore high priority for rehabilitation, are façades and infiltration. More generally, the methodology reflects the order of magnitude of benefit for various rehabilitation measures. In future work, benefits will be coupled with cost, with the outcomes helping to inform rehabilitation policy.

10. References

[1] The Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (EPDB).

[2] “La pobreza energética en el contexto de la liberalización y de la crisis económica” (Diario Oficial de la Unión Europea de 11 de febrero de 2011).

[3] “Pobreza Energética en España” (2010). Asociación de Ciencias Ambientales (ACA).

[4] CTE-HE1. Código Técnico de la Edificación. Limitación de la demanda energética, 2013.

[5] ISO_9869_1994. Thermal insulation - Building elements - In-situ measurement of thermal resistance and thermal transmittance.

[6] ISO 6781:1993. Thermal performance of buildings – Quantitative detection of thermal irregularities in building envelopes. Infrared method.

[7] UNE-EN 13829-2002: Thermal performance of buildings - Determination of air permeability of buildings - Fan pressurization.

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Spatial Quality in Building Performance Assessment Tools The case of Dwelling Renovation for Energy Efficiency

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Abstract: *The contribution of this paper is to analyse the availability of spatial quality assessment in two major building performance assessment tools that are used in Europe considering dwelling renovation: the Building Research Establishment Environmental Assessment Method UK 2008 (BREEAM UK 2008) and the Sustainable Buildings Tool (SBTool 2012). Spatial quality contributes to people's well-being and quality of life and therefore its inclusion in renovation processes gives arguments that may increase stakeholders' receptiveness to and investments in energy-efficiency renovation. This paper reveals part of the gap and the conflict between technical and non-technical dimensions in the tools, and suggests opportunities for improvement in terms of validity, reliability, sensitivity and specificity of the spatial quality assessment. Due to their relevance to (1) and wide-ranging cover of the building process, tools open up an opportunity to implement spatial quality assessment in dwelling renovation. Including more and better spatial quality indicators in the tools can contribute to raising awareness of the importance of this issue among design professionals and decision makers, and provide additional incentives for energy efficiency.*

Keywords: spatial quality, building performance assessment tools, BREEAM UK 2008, SBTool 2012, non-technical dimensions, energy renovation of residential buildings

5. Introduction

The two elements under consideration in the study are introduced in this section. The first element is spatial quality and the second element is the assessment of spatial quality available in actual building performance assessment tools used for dwelling renovation. In this section we first summarise the definition of spatial quality (2). Second, we introduce the analysis of building performance assessment tools for spatial quality assessment. We analyse two assessment tools for dwelling renovation: BREEAM (Building Research Establishment Environmental Assessment Methodology) UK 2008 for Major Refurbishment and Multi-residential Use, and SBTool (Sustainable Buildings Tool) (2012). The aim is to find out whether these tools include spatial quality and how effective they are in assessing spatial quality. BREEAM UK 2008 and SBTool (2012) have been selected for this study because of their relevance in the building industry in Europe.

The definition of the term spatial quality results from the literature review, which resulted in diverse approaches to spatial quality on the building scale being found (2). The result of the review of the literature on spatial quality is the setting up of and the definition of four

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determinants: (I) views, (II) internal spatiality and spatial arrangements, (III) the transition between public and private spaces and (IV) perceived, built and human densities (2).

The main topics of the spatial quality determinant of (I) view are: (a) the view from the inside to the outside of dwellings and from the outside to the inside (visual privacy), (b) distances between public and private domains and (c) view quality. The second determinant of (II) internal spatiality and spatial arrangements consists of the analysis of (a) the articulation between space and its boundaries, and between adjacent spaces, (b) the privacy within the dwelling and (c) light (access of daylight) (2). In (III) the transition between public and private spaces, the main topics for analysis are (a) physical barriers between public and private spaces, (b) outdoor private spaces and (c) the facade composition and permeability. The last spatial quality determinant of (IV) perceived, built and human densities considers (a) block physical boundaries, (b) the height-to-width ratio of internal block spaces and the sense of enclosure and (c) functions in the block, and built and human densities (2).

We found that spatial quality is already indirectly considered by BREEAM UK 2008 and SBTool (2012). Both tools have indicators whose issues of concern are directly related to the spatial quality definition (2), for example the fact that these tools consider the assessment of views and outdoor private spaces. This indicates the actual awareness of the relevance of non-technical dimensions such as spatial quality as well as of the potential for improvement of the tools in order to assess non-technical dimensions.

Assessment tools are designed to measure performance, and they are not necessarily the best options for guiding and promoting changes in design, despite their current influence in building processes (3). They concentrate on assessing diverse issues through metrics, checklists, scores and ratings. Most of the literature on building performance assessment tools concentrates on the technical character of the tools that indicate a 'preference for clearly measurable outcomes' (4, p. 131). Nevertheless, the inclusion of non-technical dimensions and the influence of the tools on stakeholders are as relevant as technical issues in the promotion of a sustainable building environment. Due to the widespread use of the tools, and the importance and diversity of the categories assessed, they constitute an opportunity to include and promote non-technical dimensions such as spatial quality.

6. Spatial Quality Assessment in Practice

We analysed two building performance assessment tools in the search for a spatial quality-related assessment. The sources considered for the analysis of the tools BREEAM UK 2008 for Major Refurbishment and Multi-residential Use, and SBTool (2012) are the official guidelines, the Excel® sheets and websites. For the purpose of this study BREEAM UK 2008 was calibrated to assess major refurbishment of multi-residential use. The generic version of the SBTool (2012) was calibrated to assess dwelling renovation. We considered the SBTool's maximum scope, which is the full version with all criteria assessable in the tool.

The tools BREEAM 2008 and SBTool (2012) assess the environmental performance of buildings using sets of indicators organised into diverse categories. According to the World

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Health Organization (WHO) (5), an ideal indicator should have the scientific characteristics of (I) validity (it has to measure what it is possible to measure); (II) reliability (repeated measurements by different observers have to result in similar values for the same indicator); (III) sensitivity (the ability to capture changes); and (IV) specificity (only reflecting changes in a particular situation). Indicators are generic and are only intended for assessment; they consist of a description of data that have no positive or negative values associated with them (6). The context and the aim of the assessment lead to the definition of values for the assessment.

The term spatial quality is not mentioned in the tools BREEAM UK 2008 for Major Refurbishment and Multi-residential Use or SBTool (2012). However, the tools do in fact consider elements of spatial quality (Table 1) (2). The construction industry has been influenced by building performance assessment tools (4). This is because the tools function as guidelines for design teams regarding the dimensions that need to be considered in the construction process. This indicates the potential of the tools to include non-technical dimensions, such as spatial quality, in the construction and design process.

Table 1. Overview of the spatial quality related indicators in the tools BREEAM UK 2008 for Major Refurbishment and Multi-residential Use and SBTool (2012). The indicators are classified according to their relation to the four spatial quality determinants (2).

<table>
<tr><th>Assessment Tools →
Spatial Quality Determinants ↓</th><th colspan="2">BREEAM 2008 Major Refurbishment/ Multi-residential Use</th><th colspan="2">SBTool (2012)</th></tr>
<tr><td>Views</td><td>Hea[1] 2
View Out</td><td rowspan="2">Hea 1
Daylight</td><td>F1[4] Social Aspects
(Visual Privacy)
F3 Perceptual
(View Out)</td><td rowspan="2">F1 Social Aspects
(Sunlight)
D3[5] Daylight/ Illumination</td></tr>
<tr><td>Internal spatiality and spatial arragements</td><td>*</td><td>*</td></tr>
<tr><td>Transition between public and private spaces</td><td colspan="2">Hea 15 Outdoor Space
Ene[2] 18 Drying Space</td><td colspan="2">F1 Social Aspects (Private Open Space)</td></tr>
<tr><td>Perceived, built and humand densities</td><td colspan="2">LE[3] 1 Land Reuse</td><td colspan="2">A2[6] Urban Design (Efficiency of Land Use)</td></tr>
</table>

*Spatial quality feature not considered by the tool.

[1]Category Health and Well-being (Hea)

[2]Category Energy (Ene)

[3]Category Land Use and Ecology (LE)

[4]Category F Social, Cultural and Perceptual Aspects

[5]Category D Indoor Environmental Quality

[6]Category A Urban Design, Efficiency of Land Use

BREEAM UK 2008 for Major Refurbishment and Multi-residential Use

Views, daylight and outdoor private spaces are the spatial quality related topics considered by BREEAM UK 2008. The assessment associated with the spatial quality determinants of (I) views, (II) internal spatiality and spatial arrangements and (III) the transition between public

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and private spaces is included in the categories of Health and Well-being (Hea) and Energy (Ene). The issues related to views are Hea 2 View Out and Hea 1 Daylight. Daylight is the only issue related to the spatial quality determinant of internal spatiality and spatial arrangements in BREEAM UK 2008.

Transitions between public and private spaces appear in the issues Hea 15 Outdoor Space and Ene 18 Drying Space. The provision of outdoor amenity space both for private and collective use is recommended in the indicator Hea 15 and Ene 18. However, the provision of outdoor spaces in Ene 18 is only in order to provide space for drying clothes. The spatial quality determinant of (IV) perceived, built and human densities is taken into consideration in the category of Land Use and Ecology, issue LE 1 Land Reuse. However, the issues Hea 1 Daylight, 2 View Out, 15 Outdoor Space and LE 1 Land Reuse are not included in the list of minimum standards that must be attained in order to achieve a BREEAM rating (7). Furthermore, only the issue Hea 1 Daylight is included among the BREEAM credits required for a project to be considered as innovative (7).

SBTool (2012)
Views, visual privacy, daylight and outdoor private spaces are the spatial quality related topics considered by the SBTool (2012). The assessment associated with the spatial quality determinants of (I) views, (II) internal spatiality and spatial arrangements and (III) the transition between public and private spaces is included in two categories: (F) Social, Cultural and Perceptual Aspects and (D) Indoor Environmental Quality.

The criteria related to views are F1 Visual Privacy and Sunlight and F3 View Out. Measures to increase visual privacy are recommended in the sub-criterion SBTool F1.3 Visual Privacy. In this sub-criterion F1.3, the indicator consists of the analysis of visual privacy through the number of openings to exterior views and their placement on the facade. In the indicator of the sub-criterion SBTool F1.2 Sunlight, the access of direct sunlight is measured by the percentage of ‘dwelling units whose principal daytime living areas have direct sunlight for at least 2 hours per day’ (8, tool spreadsheet8). The indicator considers the most unfavourable time of the year, 12 noon at the winter solstice. The evaluation relies on the design documentation. The indicator of the sub-criterion SBTool F3.7 Access to Exterior Views from the Interior deals with the view quality, the presence of nature and distances between exterior artefacts and the viewer.

The criterion D3 Daylight and Illumination is both related to views and to internal spatiality and spatial arrangements. The indicator of the sub-criterion SBTool D3.1 Daylighting analyses the appropriate day lighting (daylight factor) in primary occupancy areas on the ground floor of buildings. SBTool D3.1 is the only sub-criterion that is part of the minimum mandatory criteria. Transitions between public and private spaces are considered in the criterion F1 Private Open Space. The indicator of the sub-criterion SBTool F1.4 Private Open Space measures the private and collective outdoor spaces in square meters (m^2). It also

[8] SBTool Excel® spreadsheet SBT12_A_Generic_Max_3_Dsn_30Oct12

considers the percentage of homes 'that have attractive and usable private outdoor areas' (8, tool spreadsheet[9]).

Determinant (IV), perceived, built and human densities, is taken into consideration in the category of (A) Site Regeneration and Development, Urban Design and Infrastructure, criterion A2 Urban Design, Efficiency of Land Use. The indicator of sub-criterion A2.1 Land Use measures the built density expressed as the ratio between the gross floor area achieved by the design and the maximum permitted gross floor area on the site (8, tool spreadsheet[10]). All the spatial quality related sub-criteria are active by default in the design and operational phases of the renovation project, except for sub-criterion A2.1 Land Use Efficiency, which is not active in the operational phase. However, none of the spatial quality related sub-criteria are automatically active in the pre-design phase.

7. SBTool (2012) and the Potential for Development of Spatial Quality Assessment
In this section, the sub-criterion SBTool F3.7 Access to Exterior Views from the Interior is presented as an example of the analysis made of the available indicators of SBTool for spatial quality assessment. The analysis also indicates the potential for development of spatial quality assessment in the SBTool.

Indicator evaluation
Name/description: Sub-criterion SBTool F3.7 Access to exterior views from interior

- Definition/description of sub-indicators/units. 'Visual quality of exterior artefacts or natural objects and their distances from the viewer'; this can be measured in meters (m).[11] Sub-criterion F3.7 is not a mandatory in the assessment.
- Principles of classification. 'To assess the quality of exterior views available to an observer located in an interior space of a main occupancy'.[12]
- Assessment. Comparability: The indicator fulfils the requirements of comparability because of the use of scores from -1 to 5. Assessment method: Analysis of the floor plans prepared by the design team only; Applicability: The indicator is applicable to two-dimensional assessment. The assessment is performed in the design phase only.

The indicator does not specify what is meant by quality of exterior views or visual privacy. It bases its assessments on subjective concepts that give space for individual interpretations, such as: 'views are unacceptably ugly', 'visually acceptable', 'features of considerable interest' and 'natural features that are visually attractive'.[13] The indicator does not follow the scientific characteristics of an indicator of validity, reliability, sensibility and specificity (5) because the assessment is based on subjective concepts.

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[9] SBTool Excel® spreadsheet SBT12_A_Generic_Max_3_Dsn_30Oct12
[10] SBTool Excel® spreadsheet SBT12_A_Generic_Max_3_Dsn_30Oct12
[11] SBTool Excel® spreadsheet SBT12_A_Generic_Max_3_Dsn_30Oct12
[12] SBTool Excel® spreadsheet SBT12_A_Generic_Max_3_Dsn_30Oct12
[13] SBTool Excel® spreadsheet SBT12_A_Generic_Max_3_Dsn_30Oct12

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Furthermore, the sub-criterion to which the indicator belongs has a weight of only 0.24% out of 1.7% (criterion weight), the assessment is not considered mandatory, and the scale of the assessment is limited. The weight of 1.7% for the criterion F3 Perceptual is also low for its category, considering its impact on spatial quality. The building is the only object of the assessment, although the configuration of the block in which the building is located influences substantially the visual quality and distances between public and private domains. The status of the indicator indicates the potential for cooperation between SBTool and BREEAM in the development of indicators for assessing exterior views.

The score method offers reliable results for comparability, but the assessment method does not because the scores are given based on subjective assessment, such as views that are 'unacceptably ugly'.[14] The assessment uses only floor plans (two-dimensional), which, considering the complexity of visual quality and visual privacy, indicates the limitation of the assessment. The source of information for the assessment is also limited. The only material considered is that supplied by the design team; site visits done by external people are not mentioned.

8. Conclusion and Further Work

The results of the analysis of BREEAM UK 2008 for Major Refurbishment and Multi-residential Use and SBTool (2012) indicate the deficiency of these tools in assessing spatial quality. First, the study indicates that spatial quality is partially considered by BREEAM UK 2008 and SBTool 2012. Second, it indicates that the spatial quality related indicators available in these tools consist essentially of recommendations rather than sufficiently developed indicators. This is because these indicators do not fulfil the level of development necessary to be considered effective indicators according to the definitions of WHO (5) and ISO21929-1 (6). The most relevant limitation of both tools is the lack of definitions. For example, the indicators related to the access to exterior views in both tools consist of only recommendations about the need for an 'adequate view out' (BREEAM UK Hea 2) or the relevance of 'visual quality' (SBTool F3.7). Neither further direction nor clear assessments and definitions are given. However, SBTool (2012) does include visual privacy, while this is not mentioned in BREEAM UK 2008.

The analysis of BREEAM UK 2008 and SBTool (2012) indicates their large potential for the improvement of validity, specificity, sensitivity and reliability in assessing spatial quality. The results of this paper are the departure point for the development of new indicators and the improvement of existing ones to integrate spatial quality assessment into the renovation of dwellings. SBTool's spatial quality related indicators more often fulfil the requirements of the scientific characteristics of an ideal indicator than indicators of the same category in BREEAM UK 2008. For example, the sub-criteria SBTool F1.2, F1.3, F1.4 and F3.7 have indicators that measure percentages, metres and square metres (validity). That is, repeated measurements by different observers result in similar values of the same indicator (reliability). An indicator that has some kind of measurement can capture changes

[14] SBTool Excel® spreadsheet SBT12_A_Generic_Max_3_Dsn_30Oct12

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(sensitivity), because measurements can be taken repetitively, and changes in measurements are particular to a specific situation (specificity). BREEAM UK 2008 considers the spatial quality related assessment throughout the entire building process, whereas SBTool (2012) considers it only at the design and operational stages for dwelling renovation.

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References

[10] Cole, R. J. & Valdebenito, M. (2013). The importation of building environmental certification systems: international usages of BREEAM and LEED. *Building Research & Information*, volume 41, *no. 6:* 662-676, DOI: 10.1080/09613218.2013.802115

[11] Acre, F. & Wyckmans, A. (2014). Spatial quality determinants for building renovation: a methodological approach to the development of spatial quality assessment. *Journal of Sustainable Technology & Urban Development SUSB*, DOI:10.1080/2093761X.2014.923793, published online from June 2014, and forthcoming on paper version in September 2014.

[12] Du Plessis, C. (2011). Towards a regenerative paradigm for the built environment. *Building Research & Information*, volume 40, *no. 1*: 7-22.

[13] Schweber, L. (2013). The effect of BREEAM on clients and construction professionals. *Building Research & Information*, volume 41, *no. 2*, 129-145.

[14] World Health Organisation (WHO): http://www.who.int/en/. Accessed in January 2014

[15] International Standard ISO 21929-1, *Sustainability in building construction – Sustainability indicators.* Switzerland: ISO; 2011. http://www.iso.org/iso/home/standards.htm. January 2014

[16] BREEAM UK (2008) BREEAM: http://www.breeam.org/. January 2014

[17] SBTool (2012) iiSBE http://www.iisbe.org/. January 2014

[18] Nearly Zero Energy Neighbourhoods, ZenN (2012). *Seventh Framework Programme Part B, Collaborative Project with Predominant Demonstration Component* (report: project description).

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Regulatory review on the Energy Performance of Buildings towards 2020 EU´s targets. Portugal´s Case Study

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Abstract: *With the publication of the Directive on the Energy Performance of Buildings-recast, in 2010, Member States were called to develop national plans to further improve the energy performance of buildings. In this sense, Portugal reviewed its regulations on the energy performance of buildings and new regulations were published, taking effect on the 1st of December 2013. These new regulations introduced dramatic changes on calculation methods. Demands were highly increased, as well as the responsibility of all the stakeholders involved in the building sector.*

The aim of this study is to analyse the main changes and challenges introduced by the new regulations on energy performance of buildings in Portugal, and to take a critical look at our path towards the improvement of energy performance of buildings and the fulfilment of the Directive´s requirements. The focus of this study is the residential sector, as it represents the majority of our building stock.

Portugal´s Regulatoty review, Energy Performance of Buildings, Residential Buildings, NZEB, Certification System, EPC

Introduction

The transposition and implementation of the recast Energy Performance of Buildings Directive (EPBD), in Portugal, led to the review of the energy efficiency requirements of buildings, both residential and non-residential.

The first energy performance requirements were introduced in Portugal in 1991, for residential buildings and in 1998, for non-residential buildings [1]. After the publication of the Directive 2002/91/EC (EPBD), the building codes were revised and three regulations were published in 2006, introducing the National System for Energy and Indoor Air Quality Certification of Buildings (SCE), and tightening the demands on energy performance for all buildings, either new or subject to major renovation. These regulations revolutionized the way energy performance of buidings was adressed and the building sector as a whole. From designers to owners, contractors, manufacturers of building components, suppliers, installers and even municipalities, all stakeholders had to make adjustements and assimilate this new way of looking at the building sector.

Field implementation started in 2007 and, seven years later, the codes were revised and published, taking effect on the 1st of December 2013, making the transposition of the recast

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EPBD. Again, new challenges were set for the building sector, now more aware and receptive, as the first stage of implementation of the EPBD had reached a mature stage [1].

Taking into acount the experience gained over the past years, the revised regulations were improved to respond to EU's targets and to better fit the market´s needs and building sector's reality, with the contribution of nearly 100 different stakeholders and institutions in the revision process [1].

The aim of this study is to analyse the main changes and challenges introduced by the new regulations on energy performance of buildings in Portugal, and to take a critical look at our path towards the improvement of energy performance of buildings and the fulfilment of the EPBD´s requirements. The focus of this study is the residential sector, as it represents the majority of our building stock.

Building codes´ review

The building codes' review introduced major changes in some areas, the first being the fact that the previous three codes were now transposed into one, the national System for Energy Certification of Buildings (SCE - DL nº 118/2013), which integrates the Regulation on Energy performance of Housing Buildings (REH) and the Regulation on Energy Performance of Comercial and Service Buildings (RECS). This code was complemented by a series of ordinances and dispatches which alow quick and easy updates, making the regulations more flexible and adaptable to follow the roadmap towards 2020's targets.

There were also significant changes in methodologies, with the introduction of eficiency requirements for building systems for heating, cooling and DHW support, together with installation, quality and maintenance requirements. The thermal quality requirements for the building's envelope were also tightened and the maximum values for heating, cooling and primary energy needs are now set by comparison with a "reference building", which is similar to the building in study but uses optimal values for heat transfer coefficient (Uvalue) of the building´s envelope components, including glazing, optimized solar factor for windows and minimum requirements for systems´eficiency. It also considers a maximum value for natural ventilation of 0.6 ren/hr, as the minimum requirement set in the regulation is 0.4 ren/hr [2]. The reference values for heat transfer coefficients and systems efficiency are progressively tightened until 2020, with currently set values for 2013 to 31's of December 2015 and from 2016 until the next review, setting a roadmap for paving the way towards Nearly Zero-Energy Buildings (NZEB). These values were estimated based on cost-optimality [1]. So, the revised code includes a roadmap of evolutionary requirements, and a legal framework that allows quick and easy updates.

Another major change in calculations was the fact that climatic zoning changed from a degree days based on 20ºC to 18ºC. This takes into consideration the adaptive thermal comfort approach, widening the range of acceptable indoor temperature, which naturally results in less energy needs. There are still three climate zones for the heating and cooling seasons, but climate parameters are now based on the altitude of the site, thus more refined.

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Passive solutions, which were not accounted for in the previous regulations, are now part of the revised calculation methodology, including solar gains through attics and sunrooms. Shading from architectural elements is now included in the solar factor of glazing.

The use of renewable energy sources (RES) for DHW remains mandatory, but now there is the possibility to account for the use of other renewable energy systems, such as PV, biomass, geothermal, hydro, etc., provided that they supply equivalent amount of renewable energy as the solar thermal system. Priority should always be given to DHW.

Moreover, the primary energy needs' calculation also suffered major changes, by the elimination of reduction factors, which were applied to heating and cooling needs in the previous code, and by the separation of the RES contribution, which is now subtracted from the final energy needs of the building, working also as an indicator of RES use. RES are not accounted for in the reference building, so they have a very significant impact on reducing the primary energy needs of the building in study, when compared to the maximum needs of the reference building. This also allows to better define, in the future, a boundary for the percentage of RES to be used in buildings, paving the way to NZEB.

The revised code also introduced greater flexibility for existing buildings undergowing major renovation, which were subject to the same requirements as new ones in the previous code. This took into account cost-optimal analysis, as the fulfillement of the requirements proved to be excessively heavy on costs and was creating great pressure on the market. Renovated buildings only have to comply with maximum primary energy needs, affected by a majoration coefficient of 1.50, if they were built before 1960. For buildings built after 1960, there is also the need to stay below maximum heating and cooling needs, also affected by majoration coefficients. The building´s envelope and the need for RES are only subject to minimum requirements if an intervention is made on these elements/systems.

Energy Certification System

The revised code reinforced the national System for Energy Certification of Buildings (SCE), by streghtening the control mechanisms, introducing the need for certification, inspection and maintenance of building systems for heating, cooling DHW and RES and reinforcing the responsabilities of the stakeholders involved in the process.

The need to use certified components and systems was reinforced, as well as the requirements on instalation, control and maintenace, leading to the development of programes to train the workforce and requiring an adjustement of the market, quality control and energy labeling of building components (Efficient Windows Programe, for example).

Energy Performance Certificates (EPC) are mandatory for the sale or rental of existing buildings and to obtain the user licence in new buildings, or buildings subject to major renovation. The EPCs are issued by Qualified Experts (QE), which must be architects or engineers, with a minimum of five years of professional experience, who have to attend special courses and pass an exam to become QEs. The Quality Assessment (QA) of the SCE

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promotes regular inspections of the QEs work by the assessment of a random sample of the EPCs issued, in order to improve the quality of the system [1]. To issue an EPC, the QE must always perform on-site cheks. The EPCs are then inserted by the QEs, in an restricted access area, into a national database, wich is managed by the national Energy Agency (ADENE). This database allows policy makers to supervise the system and retrieve statistical data, alowing restricted access for other stakeholders, such as real estate agents, owners and researchers, to visualize the EPCs and other relevant information available.

EPCs are the way to better assess the energy performance of buildings and to analyse the potential for it's improvement. In this sense, a set of recomendations for the improvement of the building´s performance is included in the EPC, adjusted to each case. The QE issues a report, that accompanies the EPC and contains detailed information about each recomendation, including materials, estimated costs and impact on the energy performance of the building. In order to promote the implementation of improvement recomendations, ADENE is preparing an online portal where consumers can have access to more detailed information of their building, through its EPC number, and interact with the market making it easier to understand and implement improvement recomendations. Another measure taken in this sense is the elimination of the fee for issuing a new EPC, after implementation of recomendations. However, there are still litlle financial incentives in this area and the developing of special programes is needed.

Another control mechanism that has been implemented, as a way to guarantee the compliance with the code and the issuing of the EPCs, is the obligation to advertise the energy label of a building when is offered to the market, for sale or renting. An effective way to control this situation was the introduction of solidary responsability for home owners and real estate agents. This caused a boom in the issuing of EPCs in the begining of 2014, folowing the revised code´s effectiveness.

The general awareness of the population regarding the importance of energy performance of buildings is increasing, as the implementation of the first EPBD reached a mature stage. Although there is still litlle understanding of the importance of the EPCs, information campaigns and tighter control mechanisms have made the public more aware of the need to have an EPC. It is frequent to hear the complains and doubts of the owners in the begining of the certification process turn into curiosity and a different look at their building and improvement recomendations, by the time they receive the EPC. The same applies to the market, which now sees energy performance of buildings as an oportunity to offer better products and services and to invest in quality and certification. Training of experts and other technicians involved in the building sector is growing both in offer and in demmand, proving that the market is gradually preparing itself for the increasing demands on energy performance of buildings and all the aspects it envolves.

Nevertheless, the dramatic changes in methodology caused the energy class of the existing buildigs to drop, when compared to the previous code. This is due to the fact that the previous

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regulations gave too much importance to the eficiency of systems, specially for DHW, as the heating and cooling needs were affected by a reduction factor in the primary energy needs calculation. Now, the emphasys is given to the building's envelope and, when compared to the reference building, existing buildings fall below expectations. This has caused some disapointement to owners who were expecting similar energy performance classes as their neighbours, whose apartments where certified with previous code´s premisses, and then see their apartments drop down one category. In a brief analysis of the average energy class for existing buildings in the first period of implementation of the SCE and after the code´s review, we can observe a trend for lower energy clases, as shown in figure 1. This brings fragility to the system, in the public eye, and demands more information and incentives for the improvement of energy performance of existing buildings.

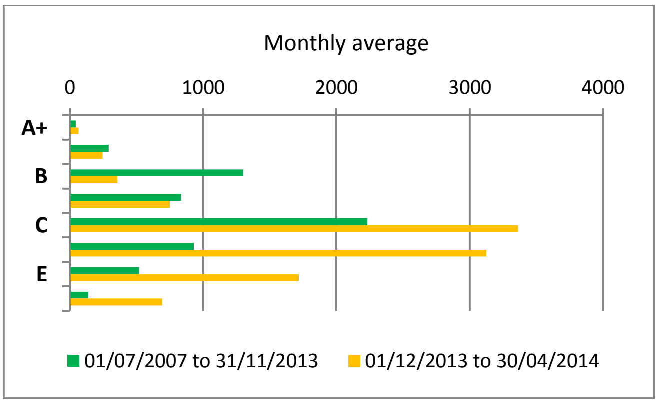

Fig. 1 – Monthly average of issued EPCs by energy class (source: ADENE)

Nearly Zero-Energy Buildings (NZEB)

Although there has been a significant evolution on the national codes on energy performance of buildings, the transposition of the recast EPBD was only concluded by the begining of December 2013, with the new codes taking effect.

This delay in the transposition of the EPBD also affected the development of national plans for the implementation of NZEBs. There is still no official definition of NZEB, but there is a roadmap towards its implementation, defined in the current code. The regulation sets up a progressive tightening of the energy performance requirements until 2020 [1] and introduces a new way to account for RES contribution in calculations, paving the path towards NZEB.

Nevertheless it is still a concept that the majority of the stakeholders is not familiar with, as it is not yet defined and disclosed. Studies are being made, but there are still no official results or examples. One of the possible paths pointed by some is the adaptation of Passive House standards, adjusted to our climate. However this is not consensuous and official definitions have not yet been pointed.

To test the roadmap set by the present revised code, we made a sensitivity study using an existing building, which rated A+ energy class with the previous regulations, and then applied the current requirements to it, to assess the changes introduced by the new methodology. Then we applied the requirements for the building´s envelope predicted on the code for 2013, for

2016 and the Passive House recommended U values for Portugal´s climate, to access the evolution of primary energy needs and the approach to NZEB values, considering a reference value for CO_2 emissions of $3kgCO_2/(m^2.yr)$ [4]. At the end we tested the influence of the systems efficiency and the use of RES, either for heating and DHW, or strictly for DHW.

The building is a single house located in Lisbon with 3 bedrooms, 2 living rooms, 1 office 4 toilets and a kithen, distributed by 3 floors. It is an original construction from the 19th century, subject to major renovation, located in the heart of the city. The existing facades in ordinary stone masonry were maintained in the ground floor and a new concrete structure was made. Traditional solutions were adopted, with 40cm external double brick walls, insulated on the cavity with 4cm of XPS, and covered by plaster. Internal walls are in brickwork, covered with plaster, or in plasterboard, with mineral wool on the inside. Pillars and beams were insulated on the outside with 6cm of EPS. Roof and floors are in concrete. The house has a pitched roof with a 12cm concrete slab, insulated on the outside with 4cm of XPS and covered with roof tiles. All the floors were insulated with 5cm of EPS, due to the installation of radiant floor.

The windows are in PVC and have double glazing with 4mm glass on the inside, 14mm air space, and 5mm glass on the outside. Solar factor of glazing is 0.65 (g-value). All windows have wood shutters on the inside, lowering their g-value to 0.46. The house faces north and has a back front to south. It is inserted in a block, with adjacent houses on both sides, reducing losses by the building´s shell.

It has a net area of 234.50 m^2 and roof height of 2.36m. Heating system is made by a heat pump with COP of 3.94 (radiant floor), which also provides cooling, with an EER of 3.67, and DHW support with a COP of 2.60. It has a solar thermal system with 4.6 m2, vacuum tube, South oriented (-4º), 28º tilt angle, partial exposure (shading SE) with a 200l water tank located in the attic, providing 2 333 kWh.yr for DHW and heating (aprox. 70%-30% estimated ratio). Ventilation is natural, with an estimated value of 0.70 ren/hr. In this study, a value of 0.60 ren/hr was considered, in the scenarios using reference values.

By observing the results, shown in figure 2, we can see that this building is already very close to the NZEB reference value considered, as it has low energy needs, efficient systems and about 50% contribution of RES. By changing the envelope's U values, according to the roadmap set in the portuguese code, we can see that the building is already better than the reference building for 2013 and almost as good as the reference building for 2016. Only when compared to Passive House standards it falls below, as cooling needs are highly reduced.

However, when using the minimum requirements for the efficiency of heating, cooling and DHW systems, CO_2 emissions increase significantly, leaving us far from the desired value.

We noticed that the best combination was to give priority to the use of RES for DHW, as already predicted on the regulation, as the same percentage of RES translated into lower CO_2 emissions if it was used to suppress DHW needs (aprox. 98%). The study demonstrated that

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NZEB levels are achievable, with the reference values for the building´s envelope predicted for 2016 and about 50% of RES, prioritising DHW production needs.

Variation on U values with actual instaled systems and RES for heating and DHW						Variation on U values with default systems and RES for DHW (minimum requirements)			Variation on U values with actual instaled systems and RES only for DHW		
U values	Heating needs (kWh/m2.yr)	Cooling needs (kWh/m2.yr)	Primary Energy (kWh/m2.yr)	Co2 emissions (kg/m2.yr)	RES (30% heating; 70% DHW)	Primary Energy (kWh/m2.yr)	Co2 emissions (kg/m2.yr)	RES (100% DHW)	Primary Energy (kWh/m2.yr)	Co2 emissions (kg/m2.yr)	RES (100% DHW)
Original project	26,1	7,8	23,19	3,41	52%						
Reference values 2013	30,1	7,8	25,78	3,84	49%	24,82	11,94	26%	24,82	3,41	51%
Reference values 2016	25,4	8,2	23	3,41	52%	22,04	10,23	26%	22,04	**2,98**	53%
Passive House recomend. Portugal	11,2	10,5	15,47	**2,13**	62%	14,51	5,54	40%	14,51	**2,13**	63%
Heating - Heat pump COP 3,8; Cooling - Heat pump EER 3,67; DHW - Heat pump COP 2,6; RES - 2333 kWh/Yr (30% heating; 70% DHW)						Default systems: Heating - electric radiator η=1; Cooling - regfrigerator machine η=3; DHW - electric termoacumulator η=0,95; RES - 2333 kWh/Yr (100% DHW = 98% total DHW needs)			Heating - Heat pump COP 3,8; Cooling - Heat pump EER 3,67; DHW - Heat pump COP 2,6; RES - 2333 kWh/Yr (100% DHW = 98% total DHW needs)		

Fig. 2 – Variation of primary needs and CO_2 emissionsacording to buildig's envelope, systems and use of RES

In this simple sensitivity analysis we can conclude that it is possible to achieve NZEB levels in Portugal, even for building renovation, and that the path set by the revised code is in line with the 2020´s targets. However this is a simple exercise for one building and further studies have to be made. Cost-effectiveness was also not considered.

Conclusions

Although the transposition of the EPBD recast has been slow, it introduced positive changes to the national regulations on energy performance of buildings. The new code promotes the enhancement of the building´s envelope and use of passive solutions and RES, as the previous regulation was very centered on the systems for heating, cooling and DHW. This contributes in a positive way to a better quality of construction and effective reduction of energy needs in the building sector, paving the way to the NZEB implementation. However, an oficial definition of NZEB and national plans for its implementation are stil in order.

The dramatic changes in regulations introduced more demanding requirements, resulting in the drop of energy class for the existing buildings. Although this methodology is more adapted to reality, it still has to earn the trust of the public, who had already embraced the certification system and now feels a bit disapointed, as it is difficult to understand the drop on the energy classes of their buildings. This requires more information and motivation campaigns, which could include the creation of special programs for the implementation of improvement recomendations. The training of the workforce and, as important, of the designers is an crucial step, still needed, for deep and real changes to occour.

References

1. Santos, P., Mateus, P., Fragoso, R. (2013) EPBD implementation in Portugal. Status at the end of 2012. *Implementing the Energy Performance of Buildings Directive (EPBD). Featuring coutry reports 2012,* 299-306.
2. *Portaria n.º 349-B/2013of the 29th of November*
3. Building Performance Institute Europe, 2011. *Principles for nearly zero-energy Buildings. Paving the way for effective implementation of policy requirements.* Bruxels: Building Performance Institute Europe (BPIE).

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Session 30:

Do sustainable buildings require complex technical innovations?

Chairperson:

Meacham, Brian, J.

Associate Professor . Worcester Polytechnic Institute. USA

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Optimization of Energy Supply Systems for a Sustainable District in Stockholm Using Genetic Algorithms

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Abstract: *Multi-objective optimization tools using genetic algorithms (GAs) are being increasingly used for improving building performances and sustainability. However, few studies focus on district-scale solutions. Here, a multi-objective optimization method using GAs was applied in order to help decision makers find the optimal energy mix of a district energy system in the preliminary design phase.*

The new Albano Campus in Stockholm was used as a case-study. Having a wide range of energy systems as design variables, three objective functions were to be minimized: the life-cycle costs; the anual greenhouse gas emissions; and the annual non-renewable primary energy consumption. The district energy balance is calculated using a steady-state method with an hourly resolution. The optimization process was implemented on MOBO, a multi-objective optimization tool based on GAs. The findings include understanding the trade-offs among the three objectives and a selection of energy supply systems to investigate in the detailed design phase.

Energy systems, multi-objective optimization, genetic algorithms, sustainable districts, Albano, MOBO

Introduction

When designing sustainable districts, planners and decision makers have to face the challenge of selecting a district energy system in order to minimize the greenhouse gas emissions and the energy consumption, while taking into account economical considerations. Assessing various alternatives is critical especially in the preliminary whase, when the most impacting decisions are made. If decision makers are provided with tools able to calculate and compare a large number of possibilities, more informed and thus better decisions can be made, resulting in an increased sustainability of the districts.

A district energy system can be defined as a set of technologies for energy conversion and distribution to building clusters or districts [1], [2]. The energy system has to be designed to provide the amount of energy needed at the required temperature level. The design of a district energy system involves the search for a 'best' solution achieving several objectives (e.g. technical, environmental or economical), and therefore belongs to the class of multi-objective optimization problems [1]. Because design objectives may be conflicting against

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each other, the solution of a multi-objective optimization problem is not represented by a single solution, but by a set of infinite solutions–the so-called Pareto front [3]. In addition, the design of a district energy system is a complex optimization problem since it involves multiple variables, both discrete and continuous, and non-linear functions. Solving the problem through a traditional iterative design process can be difficult and time-consuming, and it hardly results in an optimal design solution [4].

Multi-objective optimization problems can be better solved by automating the optimization process using a Genetic Algorithm, or GA [4]. GAs are heuristic methods that approximate the Pareto front through a converging set of solutions (a population). Using concepts inspired from evolutionary biology, such as selection, crossover and mutation, a GA generates the next population based on the previous fittest solutions, until a predefined number of iterations (generations) is reached [5].

The application of GAs to building and energy-related issues is a growing field of research. GAs were used for instance in investigating building design alternatives or optimizing HVAC systems [3], [4], [6]. Several optimization tools are available, reviewed in [7].To face the lack of existing tools, MOBO, a Multi-Objective Building Optimization software, has been developed at Aalto University [7]. Although originally intended for coupling with building simulation programs, its flexibile interface allows solving also user-defined problems.

Methodologies for the selection and design of district energy systems using multi-optimization tools can be found in previous studies [1], [2], [8]. Drawing from these works, in the present research a multi-objective methodology able to find optimal combinations of energy systems at the district level in the preliminary phase was developed in MOBO and applied to a real case study, the new Albano Campus.

Case study

The new Albano Campus is a mixed-use urban development project located in Stockholm for the extension of Stockholm University. The project, situated in an area of high environmental, historical and cultural values, has the ambitious aim to be a model of modern and sustainable campus [9]. By 2020, the district is planned to host almost 10 000 students, 1500 workers and 1100 inhabitants. Only the first construction phase, consisting of 5 academic buildings and 5 residential buildings for a total of 100 000 m^2, has been taken into consideration here. The research study has been conducted in collaboration with Akademiska Hus and Svenska Bostäder, both crucially involved in the development of the Albano Campus.

District energy system optimization

The solution strategy for the Albano case is based on four steps, represented in figure 1: (1) data gathering; (2) optimization problem formulation; (3) implementation; and (4) data post-processing. The problem formulation is mainly based on DESDOP [1]; however the calculation has been done here on a whole year, while the distribution network has not been optimized, since the plant location was fixed.

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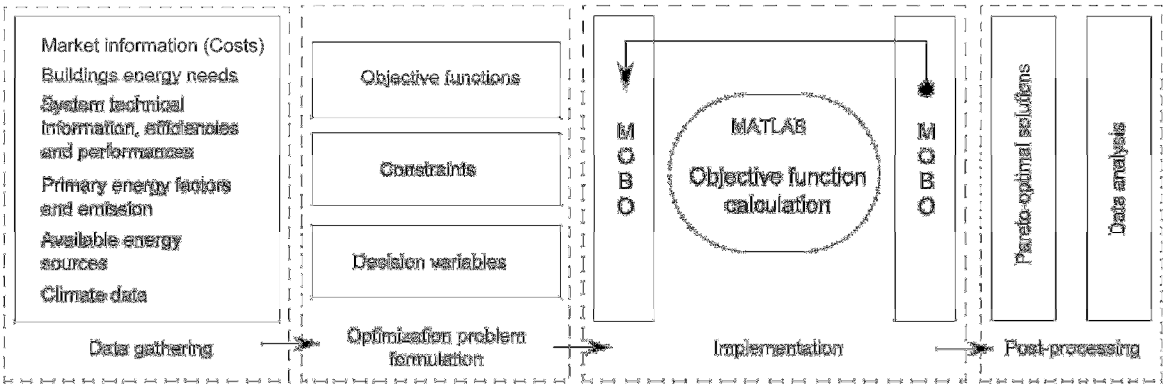

Figure 1. Solution strategy adopted for solving the optimization problema in the Albano case

Data gathering

The energy demand of the Albano Campus is represented by the hourly load profiles of heating, cooling, domestic hot water and electricity. The heating and cooling profiles were provided by Akademiska Hus from building simulations, while electricity and hot water loads had to be estimated. Since the number of buildings was limited, the same load profile has been assumed for buildings with similar functions. Climate data consisted in the hourly profiles of solar radiation and wind speed. Estimations of costs and system performances were gathered from an internal report from Akademiska Hus, from market analyses by the Swedish Energy Agency, and from the literature. For a detailed list of references, see [10].

Optimization problem formulation

The problem is based on 16 decision variables representing the system sizes (i.e. the power capacity in kW), system existence, or fuel type (tables 1). Available systems and delivered energy carriers were selected based on the energy sources found on-site and nearby. The design objectives are represented by three objective functions to be minimized [1], [11], [12]. System boundaries were defined according to Rehva technical definitions and system boundaries for nearly zero energy buildings, distinguishing between on-site, nearby and distant energy systems [11].

1) *Non-renewable primary energy consumption* $E_{\mathrm{P,nren}}$:

$$(1)\ \ f_1 = E_{\mathrm{P,nren}} = \sum_i \left(E_{\mathrm{del,n},i} f_{\mathrm{del,nren},i}\right) - \sum_i \left(E_{\mathrm{ex,n},i} \cdot f_{\mathrm{ex,nren},i}\right)\ \ [\mathrm{kWh/y}]$$

where i is the energy carrier at the nearby boundary; $f_{\mathrm{del,nren},i}$ and $f_{\mathrm{ex,nren},i}$ are the non-renewable primary energy factor for the delivered–respectively, exported– i-th energy carrier; $E_{\mathrm{del,n},i}$ and $E_{\mathrm{del,n},i}$ are the annual delivered and exported energy at the nearby boundary.

2) *Operational global warming potential* $m_{\mathrm{CO_2}}$:

$$(2)\ \ f_2 = m_{\mathrm{CO_2}} = \sum_i \left(E_{\mathrm{del,n},i} \cdot K_{\mathrm{del},i}\right) - \sum_i \left(E_{\mathrm{ex,n},i} \cdot K_{\mathrm{ex},i}\right)\ \ [\mathrm{gCO_2eq/y}]$$

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where K_i is the CO_2 emission coefficient for the i-th energy carrier in gCO2-eq/kWh. The coefficients accounts only for emissions during the operation of the systems.

3) *Levelized life-cycle costs* $\overline{LCC}$:

$$(3)\ \ f_3 = \overline{LCC} = \sum_s C_{\mathrm{inv},s} A_{\mathrm{n},s} + \sum_s c_{\mathrm{O\&}M,s} + \sum_i E_{\mathrm{del,n},i} c_{\mathrm{op,buy},i} - \sum_i E_{\mathrm{ex,n},i} c_{\mathrm{op,sell},i}\ \ [\mathrm{kr/y}]$$

where s stands for the energy system considered; $C_{\mathrm{inv},s}$ is the investment cost of the s-th system; $c_{\mathrm{O\&}M,s}$ is the cost for operation and maintenance (without fuels); $c_{\mathrm{op,buy},i}$ and $c_{\mathrm{op,sell},i}$ are the cost factor for buying–respectively, selling–the i-th energy carrier; $A_{\mathrm{n},s}$ is the annuity factor for levelizing the costs of the s-th system under a lifetime N and a constant business real discount rate i_{r}. Dismissal costs were not taken into account.

Decision variables	Range or acceptable values
Ground-source heat pump size (space heating and cooling) [kWth]	[0,2000]
Ground-source heat pump size (hot water) [kWth]	[0,2000]
Photovoltaic cells area [m^2]	[0,11000]
Solar thermal collectors area [m^2]	[0,11000]
Biomass boiler size [kWth]	[100,2000]
Reciprocating engine size [kWel]	[10,3000]
Molten carbonate fuel cell size [kWc]	[240,2800]
Absorption chiller size [kWc]	[100,2000]
Absorption chiller existence [-]	{0;1}
Anaerobic digester existence [-]	{0;1}
On-site wind turbines number [-]	{0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10}
On-site wind turbines size [kW]	{0,16; 0,49; 0,77; 0,8; 0,93; 2,2; 4; 13,1; 25,4; 30; 60}
Nearby wind turbine size [kW]	{0; 150; 250; 500; 600; 601; 800; 1300; 1650; 2000}
CHP type [0: no CHP, 1: RE, 2: MCFC]	{0; 1; 2}
CHP fuel type [1: natural gas, 2: biogas]	{1; 2}
Biomass boiler fuel type[0: no boiler, 1: pellets, 2:wood residues]	{0; 1; 2}

Table 1. Decision variables for the Albano case

The economical boundary was put at the nearby boundary, i.e. it was assumed that the nearby plant is to be built and managed by the district developers; thus the costs of the nearby plant are accounted amongs the investment and management costs. It was also assumed that the exported energy compensates for the delivered energy ($f_{\mathrm{del,nren},i}$=$f_{\mathrm{ex,nren},i}$, $K_{\mathrm{del},i}$=$K_{\mathrm{ex},i}$ and $c_{\mathrm{op,buy},i}$= $c_{\mathrm{op,sell},i}$), and that only electricity can be exported. Taxation rate, discount rate and inflation rate are assumed constant, while no fuel price escalation, tax deduction, or loan cost is taken into account.

Finally, constraint functions were defined to limit the total surface of solar cells A_{pv} and thermal collectors A_{TC} based on the available roof area, to limit the combined size of ground-source heat pump for space heating S_{RGSHP} and for domestic hot water production S_{HWGSHP}, and setting to zero the amount of district heating energy $E_{del,n,DH}$, respectively district cooling $E_{del,n,DC}$, when not required in the test cases.

$$(4)\ g_2 = A_{PV} + A_{TC} - 1100 \ \leq 0 \quad [m^2]$$

$$(5)\ g_2 = S_{RGSHP} + S_{HWGSHP} - 2 \ \leq 0 \quad [MW]$$

$$(6)\ h_1 = E_{del,n,DH} = 0 \quad [MWh]$$

$$(7)\ h_2 = E_{del,n,DC} = 0 \quad [MWh]$$

Implementation

The optimization process was implemented on MOBO, while the objective function calculation is done using a purpose-built Matlab script, where the energy systems are modeled. Detailed information about the assumptions used for modeling the technologies can be found in [10]. At each generation, MOBO creates a population assigning values to the decision variables. Then, for each individual Matlab calculates the energy balance for a whole simulation year by means of a steady-state method with an hourly resolution and it successively computes the objective functions values. Based on these values, MOBO initiates the next generation. The algorithm used is aNSGA-II, a MOBO built-in Pareto-archive GA suitable for calculations requiring long execution times [13]. The GA parameters are: crossover probability 0.80; mutation probability 0.015; 100 generations and a population size of 50 individuals.

Results

In addition to finding the global optimal solutions, the decision makers were interested to have sub-optimal solutions, where some technologies were a-priori excluded from the decision variables. For instance, the use of wind turbines was considered critical due to landscape regulations. Because the algorithm only converges towards global optimal solutions, it was necessary to solve the optimization for four cases: (1) all technologies; (2) no wind turbines included; (3) no district heating and cooling; (4) no district heating and cooling and no wind turbines. The Pareto fronts obtained for each of the four cases are shown in fig. 2

From the results it was posible to see that fuel cells appeared to be very promising technologies to reach the energy balance in a clean way, but at high life-cycle costs. Reciprocating engines belongs to optimal solutions only at small and medium sizes. Wood or pellet boiler appears in almost all optimal cases with variable sizes, indicating that they can be used as a backup technology. Photovoltaic panels are often present at large scales, at the expense of solar thermal collectors that results less performants since heat storage systems wre not included in the analysis. Ground-source heat pumps appear to be less advantageous from an environmental point of view, while performing better in terms of life-cycle costs. District heating appears in only few optimal solutions except to cover peak loads; storage systems or backup boilers could be used instead. The results also showed a potential for wind turbines especially at nearby locations.

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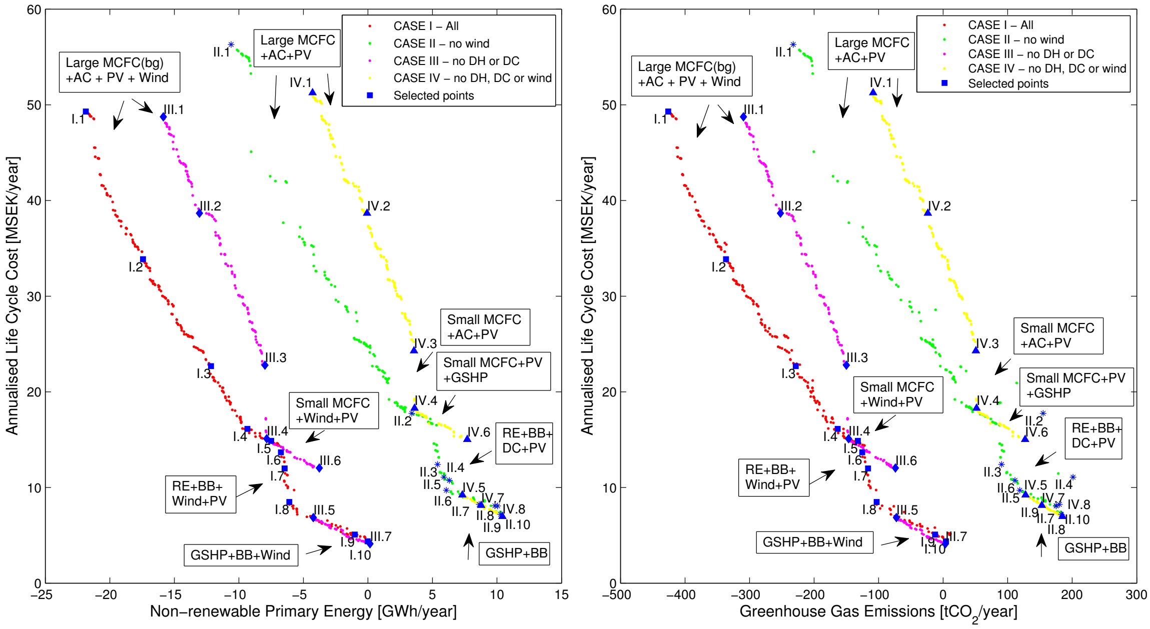

Figure 2. Pareto fronts for the four test cases considered, projected onto the planes of objective functions f_1-f_3 and f_2-f_3. Solutions in the blue color are representative solutions. MCFC: molten-carbonate fuel cells; AC: Absorption chiller; PV: solar cells; GSHP: ground-source heat pump; BB: biomass boiler.

Discussion

In this research, a multi-objective optimization method for the multi-objective design and selection of district energy systems has been succesfully applied to a real case study, the new Albano Campus. The methodology, involving coupling MOBO with Matlab, has proven to be flexible, easy to set up and requiring limited input data. The procedure can represent the compromises between the different objectives, without needing to define weights as in multi-criteria analyses; thus, the method can lead to better represent the complexity of real cases in which no single optimal solution exists.

Limitations of the analysis lie in the post-processing of multi-objective and multi-variable data, due to its inherent complexity. A better graphical user interface of MOBO, including tools of visualization techniques of the data, could help overcome the problem. It should also be further investigated which data –and in which form– should be handed over to the decision makers, to do not overload them with information, yet providing them the necessary insight into complexity. Sensitivity analyses need to be conducted to evaluate the robustness of the solutions obtained, in particular to variations of parameters most affected by uncertainty, such as economic parameters or operative perfomances of innovative technologies.

In further studies, additional objectives can be implemented, for example to maximize the exergy efficiency of the system. More technologies (e.g. storage systems) can be included. Optimizing the distribution network (see [1]) could lead to better represent energy exchanges between buildings and between nearby districts, and the tradeoffs between decentralized and centralized technologies. Positive effects of simultaneously optimizing the district energy systems and the building design and systems should also be further investigated.

[1] Weber, C. I. (2008) *Multi-objective design and optimization of district energy systems including polygeneration energy conversion technologies*. Doctoral thesis. Lausanne. Ecole Polytechnique Fédérale de Lausanne.

[2] Lu, H. (2013) *Energy quality management for new building clusters and districts*. Doctoral thesis. Stockholm. KTH Royal Institute of Technology.

[3] Alarcón-Rodriguez, A. D. Ault, G. Galloway, S. (2010) Multi-objective planning of distributed energy resources. A review of the state-of-the-art. *Renewable and Sustainable Energy Reviews,* 14(5): 1353–1366, doi:10.1016/j.rser.2010.01.006.

[4] Evins, R. (2013). A review of computational optimisation methods applied to sustainable building design. *Renewable and Sustainable Energy Reviews*, 22: 230–245, doi:10.1016/j.rser.2013.02.004.

[5] Goldberg, D. E. (1989) *Genetic algorithms in search, optimization, and machine learning*. Reading. Addison-Wesley, Inc.

[6] Banos, R. Manzano-agugliaro, F. Montoya, F. G. Gil, C. Alcayde, A. Gómez, J. (2011). Optimization methods applied to renewable and sustainable energy. A review. *Renewable and Sustainable Energy Reviews,* 15(4): 1753–1766, doi:10.1016/j.rser.2010.12.008.

[7] Palonen, M. Hamdy, M. Hasan, A. (2013). MOBO. *A new software for multi-objective building performance optimization.* 13th Conference of International Building Performance Simulation Association. Chambéry.

[8] Weber, C. I. Shah, N. (2011). Optimisation based design of a district energy system for an eco-town in the UK. *Energy,* 36(2): 1292–1308, doi:10.1016/j.energy.2010.11.014.

[9] Marcus, L. Barthel, S. Colding, J. Erixon, H. Erntson, H. Grahn, S. Torsvall, J. Kärsten, C. (2010) *Q-book Albano 4: Sustainability*. Stockholm. Akademiska Hus.

[10] Magny, A.A.A. (2014). *Optimization of energy systems for a sustainable district in Stockholm using genetic algorithms. The case of Albano*. Master thesis. Stockholm. KTH Royal Institute of Technology.

[11] Kurnitski, J. (2013) *REHVA nZEB technical definition and system boundaries for nearly zero energy buildings.* Bruxelles. REHVA Federation of European Heating, Ventilation and Air Conditioning Associations.

[12] Dinçer, I. and Zamfirescu, C. (2011) *Sustainable energy systems and applications*. New York. Springer, Inc.

[13] Hamdy, M. Palonen, M. and Hasan, A. (2012). *Implementation of Pareto-Archive NSGA-II algorithms to a nearly-zero-energy building optimization problem*. 1st Building Simulation and Optimization Conference (BSO12). Loughborough University.

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Characteristics of design process in Life Cycle Carbon Minus House

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Abstract: *The LCCM (life cycle carbon minus) house is a detached house that consumes low energy. It also generates energy and the amount is same as or more than its energy consumption by using on site renewable energy systems (ex. photovoltaic). The aim of this study is to clarify the characteristics of design process of the LCCM house by focusing on "trade-off" relations that emerged from considerations on the LCCM demonstration house. To realize the concept of the LCCM house, it is necessary to reduce both Operating CO2 and Embodied CO2. However, the idea to reduce Operating CO2 sometimes conflicts with the way to reduce Embodied CO2. This paper reports following "trade-off" aspects in particular, 1) trade-off in the design of building skin, 2) trade-off in the design of sunshade, 3) trade-off in the design of thermal mass and resident's comfort. These alternatives show the diversity of the LCCM house.*

Keywords, LCCM (LifeCycleCarbonMinus), Design process, LCA (LifeCycleAssessment), CO2 emission, Embodied CO2, Renewable energy, Detached house, Passive design,

1. Introduction

The LCCM (life cycle carbon minus) house is a detached house that consumes low energy. It also generates energy and the amount is same as or more than its energy consumption by using on site renewable energy systems (ex. photovoltaic). This project has started in 2009 and a demonstration house was constructed in Tsukuba, Japan in 2011. (Photo.1, 2, Fig.1)

The LCCM demonstration house is two storied wooden house. It was built by Japanese conventional framework system. It was designed as the house for a typical family of four residents. The aim of this study is to clarify the characteristics of design process of the LCCM house by focusing on "trade-off" relations that emerged from considerations on the LCCM demonstration house. First of all, this paper mentions the survey and analysis concerning the design process of the LCCM demonstration house. Secondary, it explains what kind of "trade-off" emerged and how we designed them through the design process of the LCCM demonstration house.

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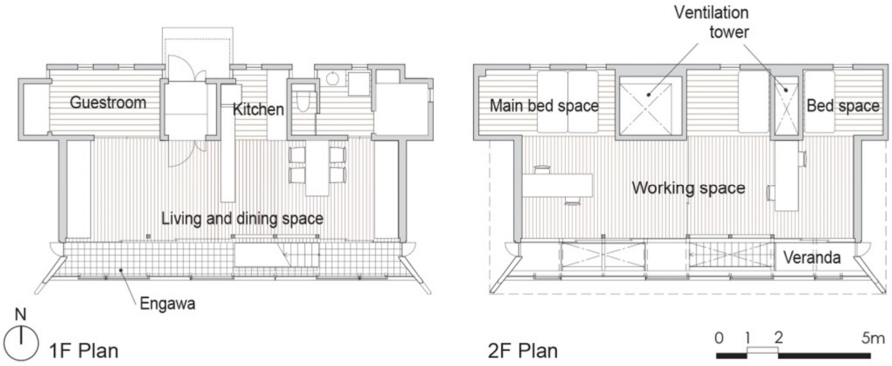

Photo.1 Exterior, Photo.2* Interior (below) *photo by koichi TRIMURA*
Fig.1 Plans of LCCM demonstration house

2. Survey and analysis concernimg design process of the LCCM demonstration house
The LCCM house is aimed to reduce the CO2 emissons in a lifetime of buildings which includes the production, construction, operation and discard phase. Its concept is defferent from other ecological houses which focuses mainly on operating energy consumption. It is expected that the LCCM house differ from most conventional houses in terms of the design process. Therefore, we try to record and analyse the design process of the LCCM demonstration house.

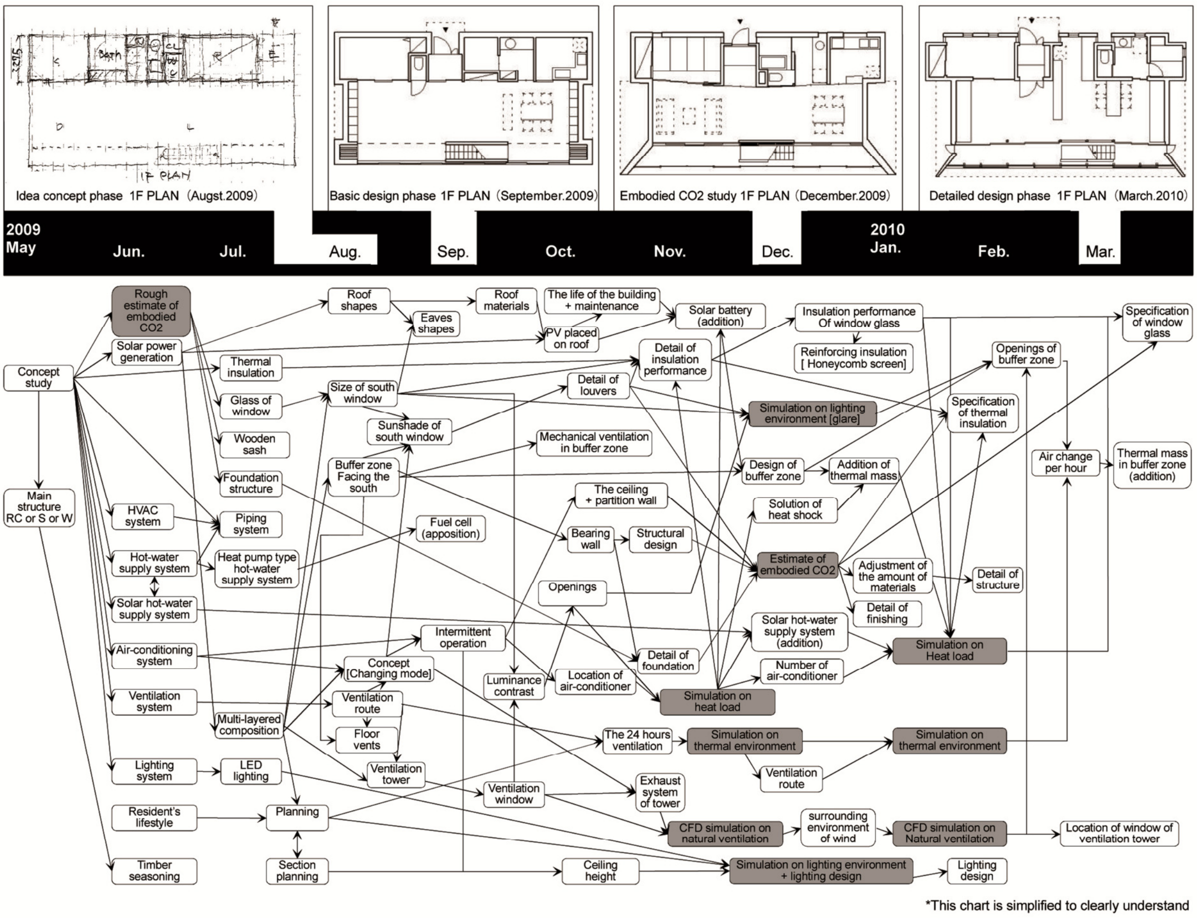

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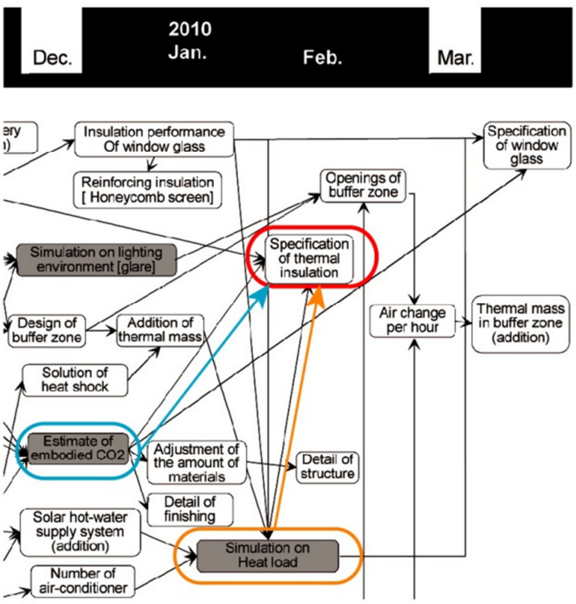
Fig.2 The network chart of design process of the LCCM demonstration house

Fig.2 is the network chart that indicates the relations of factors considered in its design process. This chart is based on the sketches and drawings, the minutes of meetings and the interview with designers. Arrows connect related factors and show their contexts. For example, the simulation on heat load of the building is held before the study on the thermal insulation performance. This chart shows important charactaristics of the design process as follows: (1) In the early stage, it is necessary to roughly estimate the CO2 emissons and to forecast the requirements of renewable energy. (2) In the early, it is required to study the way of HVAC system. (3) In the middle, it is required to estimate the embodied energy and to study LCCO2 of the building. It is like estimating the approximate cost.These features indicate the design process of LCCM house requires to examine some specifications in detail earlier than other general conventional houses. These kinds of predictions are important characteristics to design the LCCM house.

3. “Trade-off” relations in the network chart

Focusing on the detail of the network chart, “trade-off” relations emerge among some factors. For example, the decision of specifications of thermal insulations required examing both the simulation on heat load and the estimation of the amount of CO2 emisson during construction, repair and demolition. (Fig.3) The simulation on heat load examined the effect of reinforcing thermal insulation according to proper thermal environment. It relates to operating energy. On the other hand, the amount of CO2 emissons during construction, repair and demolition, that means the embodied CO2, might be influenced by reinforcing thermal insulation. Because this kind of improvement sometimes causes the increase of amount of insulation material and subsidiary material. It indicates that the specifications of thermal insulation should be studied from the perspective of both operating and embodied energy. In the same chart, the specifications of windows are studied from the perspective of both operating and embodied energy likewise. (Fig.4) These exmples suggest that the idea for reduction of Operating CO2 and Embodied CO2 sometimes are related as “trade-off”.



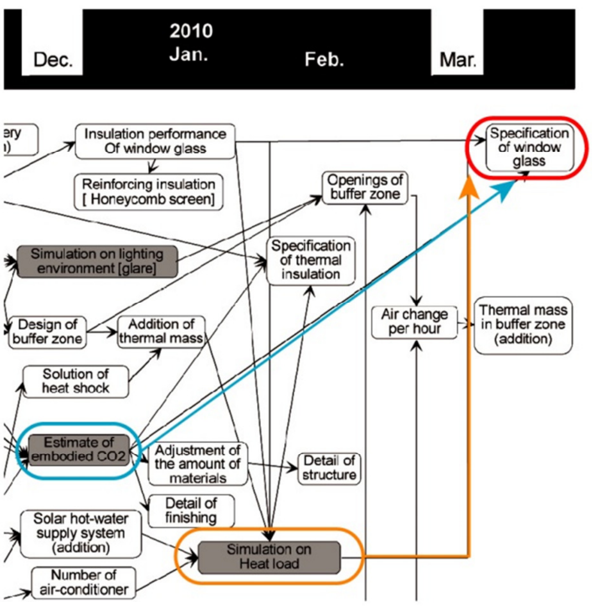


Fig.3 Design process of specifications of thermal insulation (left)
Fig.4 Design process of specifications of window glass

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Therefore, the design of LCCM house demands us to solve various “trade-off” relations responding to its concept.

4. Elements on “trade-off” relations

Table.1 shows the percentage of primary energy consumption of the normal house in Japan. It suggests that energy comsumption of hot water supply is the largest. Energy consumption of thermal environment including air-conditioning and ventilation is the second largest. Energy consumption of thermal environment changes significantlry depending on plans and performance of the building. It is considered an important factor of the design process. Therefore, this paper focuses on “trade-off” relations in themal environment and what kind of elements are concerning “trade-off” relations. We report following “trade-off” aspects in particular, 1) trade-off in the design of the building skin, 2) trade-off in the design of the sunshade, 3) trade-off in the design of thermal mass and resident’s comfort.

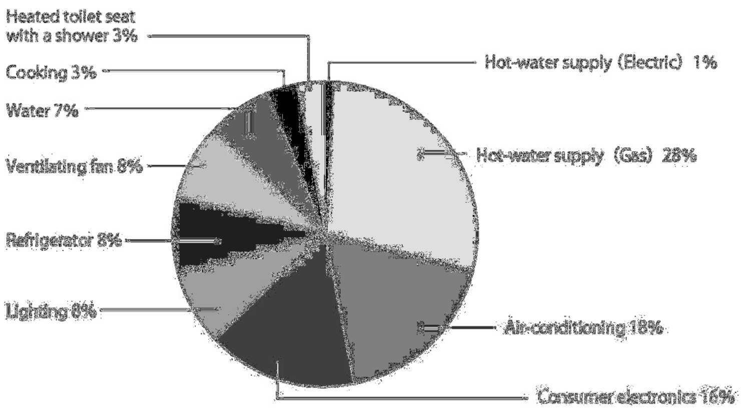

Table.1
Percentage of primary energy consumption[1)]
(An example of general detached house in 2000, Japan)

4-1. “Trade-off” in the design of the building skin

The building skin is mainly composed of roofs, walls, floors and windows. In the view of thermal environment, more detail elements, as thermal insulation material, glass of window and the others, are included. Furthermore, there are some design strategies whether building skin is single-layered or multi-layered. Table.2 shows the relations between the elements of building skin and CO2 emissons of operating and embodied phase. In addition, Table.3 shows Environmental load unit in accordance with building materials. These tables show a tendeny that the higher paformance of reduction operating energy these elements have, the larger embodied energy they require. Concerning these elements, the LCCM demonstration house is designed to achieve appropriate balance between operating and embodied CO2. Therefore, glass wool was selected as the proper type of insulation material, because it is well-balancesd operating and embodied CO2. Besides, it is fully filled only between stads to avoid increasing the amount of subsidiary materiarls.

With regard to openings, south windows are enlarged to gain more solar radiation heat. In contrast, north windows are minimalized to reduce the heat loss. Forthermore, vaccum multiple glass is selected instead of nomal multiple glass. It enables to increase thermal resistance with a less amount of materials.In addition, it is equipped with multi-layerd building skin and buffer zone to respond to change of the seasons and various human

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activities. (Fig.5, Photo.3) It is the flexible building skin that makes sharp contrast with the single, strong skin.

Elements of building skin				Performance of reducing operating CO2	Amount of embodied CO2
Roof wall Floor	Types of thermal insulation materials	Glass wool , Rock wool		Middle	Middle
		Polystyrene foam insulation board, Polyurethane foam insulation board etc...		High	Large
		Cellulose insulation, Sheep's wool etc···		Low	Small
	Location and thickness of thermal insulation materials	Exterior insulation		High ⇔ Only plastic foam board	Large (Plastic foam board + Subsidiary material)
		Interior insulation	Between the studs (Structural minimum	Middle ⇔ Limited thickness	Middle (Only for insulation
			Between the studs + α (structural minimum thickness+ α)	Middle + α ⇔ Limited thickness + α	Middle + α (Insulation materials + Subsidiary material)
Window	Types of glass	Glazing type	Single glass	Low	Small
			Double glass	Middle	Middle
			Triple glass	High	Large
	Size of windows on the south side	Large		Decreasing insulation ⇔ Gaining more solar energy	Large (Increasing glass volume)
		Small		Increasing insulation ⇔ Gaining less solar energy	small (Decreaseing glass volume)
	Window frame materials	aluminium		Low	Large
		wood		High	Small
Multi-layered composition	Single layer			Less flexibility	Depending on the plan
	Multi layer	Inner partitions for reinforcing insulation (Wood partitions, Shoji screens etc···)		High (depending on the operation)	Depending on the plan
		Buffer zone (Sunroom, Engawa etc···)		High (depending on the operation)	Depending on the plan

Table.2 The relation between operating CO2 and embodied CO2 in elements of building skin

Specificaton	Unit	Material input (kg/unit)	Environmental load unit kg-CO2/☆
Nomal concrete (Portland) Fc24N/mm2	m3	2,284.0	296.1
Steel frame (blast furnace)	kg	1.0	1.5
Lumber	kg	1.0	0.3
Glaed laminated wood	kg	1.0	1.1
Glass (single)	m2	15.2	14.2
Glass (multi)	m2	30.5	28.4
Thermal insulation material (Glass Wool 24K)	m3	24.0	66.6
Thermal insulation board (Urethane foam No.1)	m3	45.0	146.1

Table.3 Environmental load unit of building materials[2)]

Photo.3 Varieties of layer

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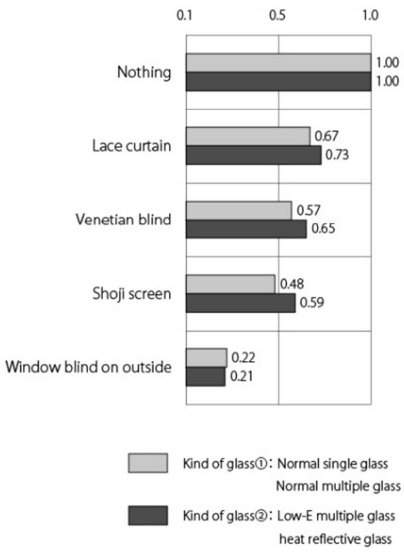
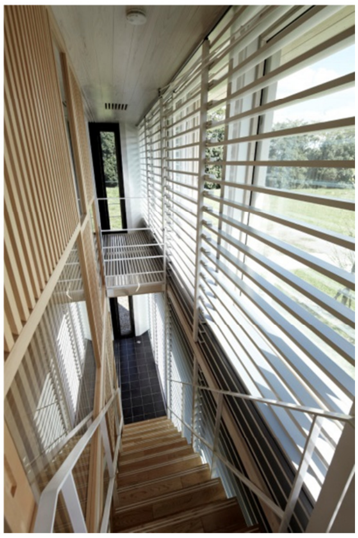
4-2. “Trade-off” in the design of sunshade

“Trade-off” relations emerge in the design of sunshade likewise. Table.4 shows the relations between Operating CO2 and Embodied CO2 in some typical ways of sunshade. Table.5 indicates that blind on the outside of glass is most effective way, but it often requires larger embodied energy beause of using some kinds of metal materials to improve weather redistance. The LCCM demonstration house is equipped with the wooden sunshade louver under the eaves, considering weather resistance. It is expected to obtain the simular effect as blind on outside by opening the wooden window in the summer. (Photo.3)

Elements of building skin			Performance of reducing operating CO2	Amount of embodied CO2
Lace curtain	Fabric types	Synthetic fibers	Low	—
		Natural fibers	Low	Small
Venetian blind (Interior)	Material of slats	Aluminium	Middle	Large
		wood	Middle	Small
Shiji screen	Japanese traditional partition (wood and paper)		Middle	Small
Window blind on outside	Material of slats	Aluminium	High	Large
		wood	High	Small
Sudare (bamboo blind)	Material of slats	Aluminium	High	Large
		wood	High	Small

Table.4 The relation between operating CO2 and embodied CO2 in elements of sunshade





4-3. “Trade-off” in the design of thermal mass and resident’s confort

Appropriate amount of thermal mass is a critical issue to get suitable indoor thermal environment for wooden houses. Generally, increase of thermal mass tends to stabilize room temperature. However, the higher volumetric specific heat materials have, the larger embodied enrgy they require. (Table.6) It means “trade-off” relations between thermal mass and stability of thermal environments. (Table.7)

In the LCCM demonstration house, the operating mode of air-conditioner was decided as the intermittent because their quick respose and low operating enrgy are preceded. Therefore, the main room and workspaces, which are air-conditioned spaces, are composed of lightweight materials that have less thermal mass and low embodied CO2. Whereas only the floor of the buffer zone, which is next to the main room, is finished by black tile for gaining solar heat and avoiding heat shock.

Material		Effective thickness (m)	volumetric specific heat (kJ/ m³・℃)
Concrete	Nomal concrete	0.2	2013
	Lightweight concrete	0.07	1871
Plastering material	Mortar	0.12	2306
	Plaster	0.13	1381
	Gypsum plaster	0.07	2030
	Mud wall	0.17	1327
Wood	Pine	0.03	1624
	Japanese ceder	0.03	783
	Japanese cypress	0.03	933
	Lauan	0.04	1034
	Plywood	0.03	1113
Board	plaster borad	0.06	854
	Pearlite borad	0.06	820
	flexible board	0.12	1302
	Wooden fibre cement board	0.06	615
The others	Tiles	0.12	2612
	Rubber tiles	0.11	1390
	linoleum	0.15	1959

		Thermal mass	
		Large	Small
Indoor thermal environment	controllablity of room temperature	Easy	Hard
	Air-conditioning	The continuos operation is better.	The intermittent operation is better.
		Slow response	Quick response
	Direct gain (Solar energy)	Effective	Hard to controll room-temperature

5. Conclusion

As stated above, in design process of the LCCM house, “trade-off” relations between operating and embodied phase become the problem to be solved. In case of the LCCM demonstration house in Tukuba, contents 4-1~4-3 are examined in view of thermal environment in particular. And, it is designed by not only studying on the balance of operating energy and initial energy, but also taking qualitative factors which are resident’s lifestyles and climate and natural features of a region into account.

It means that holistic design processes involving to study on total balance are required. Furthermore, they shoud not be treated as the additional process which ask for higher building performance blindly. At the same time, qualitative factors, such as resident’s lifestyles and climate and natural features of a region, can make alternatives of the LCCM house. A further study of the diversity of the LCCM house should be conducted.

6. References

[1] Design Guidelines for Low Energy Housing with Validated Effectiveness, Supervision: institute for land and infrastructure Management・Building research institute, Publication:Institute for Building Environment and Energy Conservation (in Japanese)

[2] Guideline for LCA of buildings, Edition: Architectural Insutitute of Japan (in Japanese)

[3] Kozo Kadowaki et al., Design Process of the Demonstration House for the “Life Cycle Carbon Minus” Concept, Summaries of technical papers of Annual Meeting AIJ. E-1, Aug.,2011

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Energy-Saving Technologies Incorporated in a Low-Carbon Office Building Located in Tokyo (Best Papers SB13 Singapore)

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Abstract: *This paper describes energy-saving technologies incorporated in a low-carbon office building located in Tokyo. The air-conditioning system that combines a centralized system and heat pump package systems reduces energy consumption. The ductless air-conditioning system reduces material usage and keeps floor height to a minimum (3.5m) while securing a maximum ceiling height (3.17m) by combining with a full flat slab. The measurement results demonstrate that COP of the air-conditioning system is high and that the ductless air-conditioning system can prevent drafts from occurring in the occupied zone. The building also employs an energy-saving lighting system utilizing indirect lighting in addition to standard downward lighting. This system reduces energy consumption while making the indoor luminous environment bright and comfortable. Measured energy consumption for the lighting was 6.8 W/m*^{2}*, which is about half of that for standard office buildings in Japan. Annual* CO_2 *emissions for the whole building were around 37.5 kg-*CO_2*/(m*^{2}*•year), which is a 62.5% reduction compared to standard office buildings in Tokyo.*

Low-carbon office, centralized system, heat pump pachage system, ductless air-conditining system, perceived brightness evaluation

Intoroduction

Approximately one-third of the total CO_2 emissions in Japan are emitted from the building and construction sector. As the proportion of these emissions is increasing, finding ways to further improve the energy-saving performance of buildings is an important theme. This paper describes the energy-saving technologies introduced in a low carbon office building in Tokyo. An outline of the building is presented, followed by a report on the performance verification for the air-conditioning system that combines a centralized system and heat pump package systems. The performance of the dustless air-conditioning system is verified in detail. An energy-saving lighting system utilizing indirect lighting is also introduced and verified. The annual electricity for the building as a whole is also reported.

Outline of the Building

The building is an office building located in the city of Chofu in Tokyo, built as a research facility. It consists of one basement floor and five aboveground floors, with a total floor area of 8,913 m^2. Photo 1 shows the exterior view of the building. Figure 1 shows the floor plan on a standard floor. Figure 2 shows the interior of the office space. Figure 3 shows a cross-section of the standard floor. The building is of reinforced concrete construction using full flat slabs with no beams. The skeleton shape of the exterior is a clear-cut flat slab (with a thickness of 330 mm) structure, with eaves protruding 1.15 m on the outside of the south

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Photo 1 Exterior View of the Building.

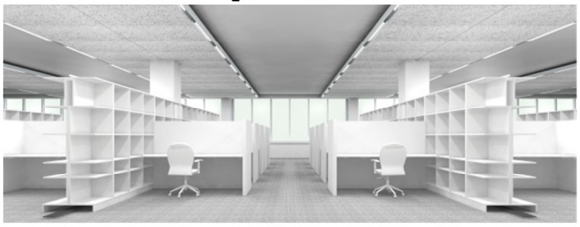

Figure 2 Interior View of Office Space.

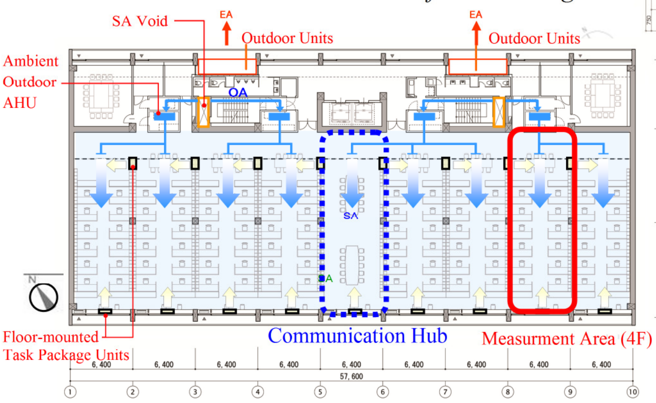

Figure 1 Plan of Standard Floor (3F to 5F).

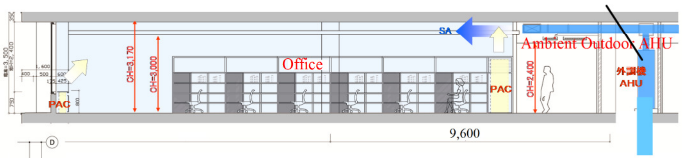

Figure 3 Cross-section of Standard Floor.

windows that consist of single-sheet glass and venetian blinds. The resulting facade provides a balance between ensuring a good view and providing sunlight-blocking performance. As a measure to prevent cold drafts in the area around the windows in the wintertime, the return air for the perimeter indoor air-conditioning units is taken in from slits beneath the windows. The office area has no ceiling panel nor raised floor in order to conserve resources by keeping the use of interior materials to a minimum, and also with the aim of streamlining the construction and ensuring economic rationality. To ensure the sound absorbing performance of the ceiling, wood wool cement boards are placed at the boundaries between each span. Moreover, to provide the functions of a free access floor, wiring space is provided in the baseboard section beneath the shelves at the boundaries between spans to secure power and LAN wiring routes to individual work booths. Eliminating free access floors and using flat slabs for the ceiling made it possible to secure a ceiling height of 3.17 m despite the low floor height of 3.5 m.

Outline of Air-conditioning System

The air-conditioning system for the building consists of air-source heat pump chillers (HP chillers) + outdoor air handling units (AHUs) and separate-distributed heat pump package air conditioners (task package systems), with the centralized system for base operation (ambient outdoor AHUs) and the task package systems for intermittent operation (Hiromoto et al., 2011 and 2012-2013). HVAC is provided by four ambient AHUs on each floor and one task package system for the interior and perimeter of each span (see Figure 1). In addition to processing the outside air, the ambient outdoor AHUs also process the base indoor load (heat produced by lighting and by common office equipment) as well as humidification and dehumidification. They detect the indoor temperature and control the supply temperature. They are also equipped with CO_2 concentration control and variable air volume control that is capable of cooling with outside air during intermediate seasons, and a ductless air-conditioning system that discharges supply air from the ambient outdoor AHUs along the

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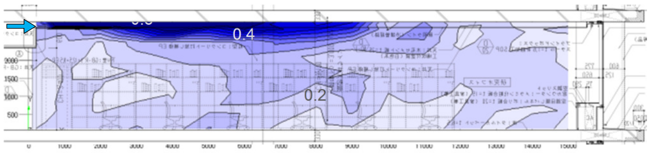
ceiling. The task package for each span has a single outdoor unit to control the interior unit and the perimeter unit.

Utilization of Ductless Air-conditioning System

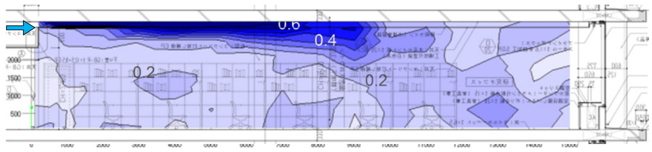
The ductless air conditioning system uses the flat slab surface of the ceiling to supply air from the interior to the perimeter without the use of ducts. The system uses the Coanda effect, in which the planar airflow from the supply slits flows along smooth, flat surfaces. This system conserves resources through the reduction of ducts, provides an ornamental effect through the use of slabs for an exposed ceiling, and reduces the floor height and provides an ample ceiling height. While the ductless air-conditioning system offers major advantages, it was anticipated that drafts might occur during the cooling period, inconveniencing building occupants. This section describes the content of the studies conducted with these issues in mind, as well as the results of the performance verification conducted after the building was completed.

In the design stage, CFD simulation was conducted to a standard span. The results for the temperature differential with the air supply (ΔT = 10°C) confirm that, due to the Coanda effect, the supply air flows along the ceiling as it flows from the supply outlet, and that a separation of the flow from the ceiling surface occurs approximately 8-9 m from the supply outlet. It had been predicted that a residual air velocity of approximately 0.4 m/s would remain at around FL +1.5 m, but it was limited to the central corridor area, so there is little likelihood that the airflow that separated from the ceiling surface and descended will reach directly to the individual seats. Full-scale mock-up tests were also conducted to confirm the air velocity and temperature distributions in the occupied zone. The measurement results were generally equivalent to the results of prediction using CFD. Even with a supply temperature differential of 10°C, it was predicted that there would be little danger of drafts occurring.

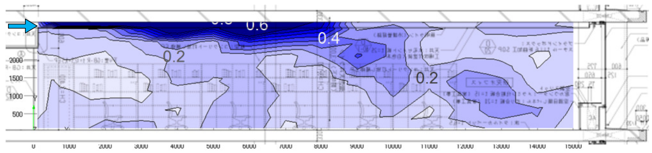
Indoor air velocity and temperature distributions were measured after the completion. The measurements were conducted for a representative span on the 4th floor (Figure 1) on July 11 and 12, 2011, before the occupants moved into the building. The velocity distributions under various conditions at the supply outlet central section are shown in Figure 4. The results show that the velocity level in the occupied zone is approximately 0.2 m/s or less. There was little difference in the trend at an air volume of 732 m^3/h as compared to 610 m^3/h, but at 305 m^3/h



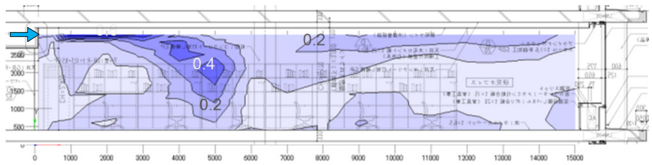
(1) Case 1-1 (610m³/h, isothermal condition)



(2) Case 1-3 (610m³/h, Δt= 10°C)



(3) Case 2-3 (732m³/h, Δt=10°C)



(4) Case 2-5 (305m³/h, Δt=10°C)

Figure 4 Velocity Distribution (Central Plane) [m/s]

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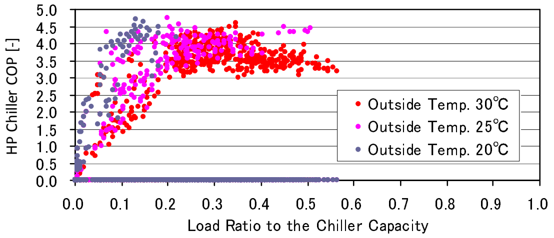

Figure 5 Cooling Load Ratio vs. COP of Air-source Heat Pump Chiller in Summer.

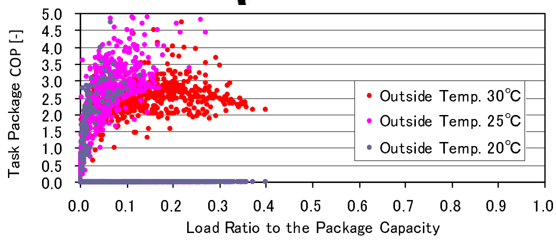

Figure 7 Cooling Load Ratio vs. COP of Separate Package Air-conditioning Systems in Summer.

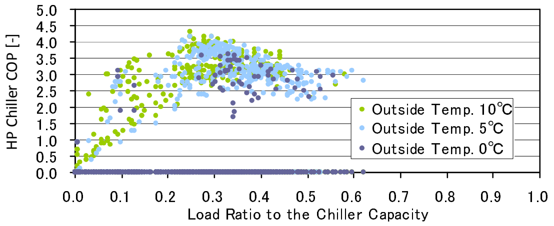

Figure 6 Heating Load Ratio vs. COP of Air-source Heat Pump Chiller in Winter.

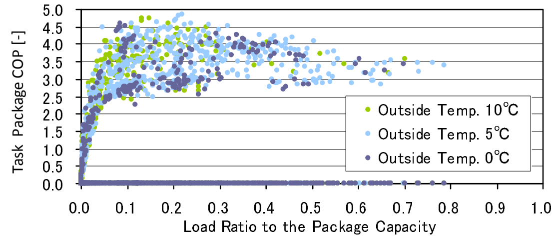

Figure 8 Cooling Load Ratio vs. COP of Separate Package Air-conditioning Systems in Winter.

it was confirmed that the airflow began to separate from the ceiling at a distance of approximately 4 m from the supply outlet. This is considered to be because the reduced supply air velocity decreased the Coanda effect. However, the velocity level in the occupied zone was approximately 0.2 m/s, and the air temperature distribution was also within 1°C, so the level is not considered to pose problems for operation. The results of the temperature distribution revealed that the temperature level in the occupied zone was held to approximately 25-27°C. Based on these results, it was confirmed that, with proper planning, the occurrence of drafts in the occupied zone could be prevented with this system.

Air-conditioning Efficiency (COP)

An analysis was conducted to evaluate the coefficient of performance (COP) of the HP chiller connected to the ambient outdoor AHUs. Figures 5 and 6 show the cooling and heating load ratio to the chiller capacity in summer and winter and the correlation with the system COP. In accordance with the main purpose of operation for the ambient system, a comparatively high load ratio of 40-50% was achieved in both summer and winter. Moreover, the properties of the air-sourced HP chiller were clearly evident: in summer the COP increased as the outside air temperature decreased, and in winter the COP increased as the outside air temperature increased. Figures 7 and 8 show the correlation between the cooling and heating load ratio and COP of separate package system in summer and winter. Due to the fact that these packages were operating intermittently, the load ratios were low in both summer and winter, but overall the system was able to operate at a comparatively high COP.

Task/Ambient Lighting that Considers Perceived Brightness

In Japan, task lighting is generally not used, and in many cases only ceiling lighting is used to make the desktop surface illuminance uniformly 750 lx. The combined use of task lighting and ceiling lighting to restrict the ambient lighting inside the room to 300 lx is an effective means of lowering electricity. However, offices that employ both task and ambient lighting are less bright due to the lower luminance of ceiling and wall surfaces, and for this reason

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little progress was made in increasing the use of these systems for many years. In the offices in this building, luminance images were estimated through simulations at the initial design stage, and indicators of perceived brightness were determined from these luminance images to realize task and ambient lighting that makes occupants feel that the space is bright.

Figure 9 shows an outline of the lighting systems. Fluorescent lights for ceiling indirect lighting have been provided above the high bookshelves. The desktop illuminance obtained from this indirect lighting alone is 70 lx, but the luminance of the ceiling surface is increased efficiently to make occupants feel that the room is comfortably bright. To ensure floor visibility and safety, the lighting has been combined with direct lighting from fluorescent lights. The desktop illuminance obtained from this direct lighting alone is 300 lx. LED lighting, which makes it possible to adjust color temperature, was used for task lighting.

These lighting systems were finalized after conducting a study using computer graphics to ensure that a feeling of perceived brightness could be kept as good level efficiently with a small amount of power (Figure 10). The study of perceived brightness was conducted using brightness impression indicators that were developed based on the subjective experiment results (Sakata, 2010). Specifically, the average value for the "Natural scale Brightness (NB)" (Nakamura, 2006), shown in a brightness image that takes into account the adaptive effect, was determined within a pitch angle of 0-20°, and the perceived brightness in the peripheral field was assessed in sedentary

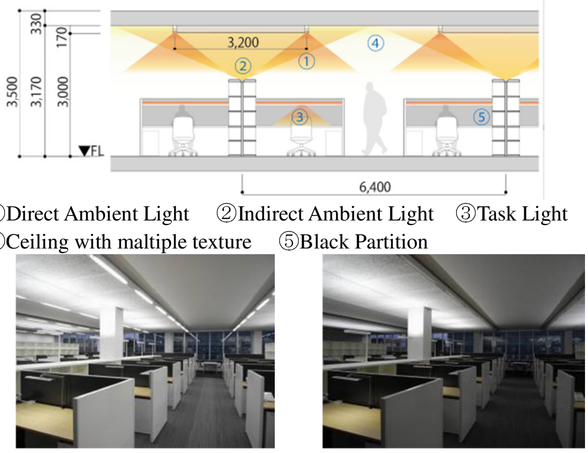

Figure 9 Outline of the Lighting Systems.

Figure 10 Brightness Image by Simulation.

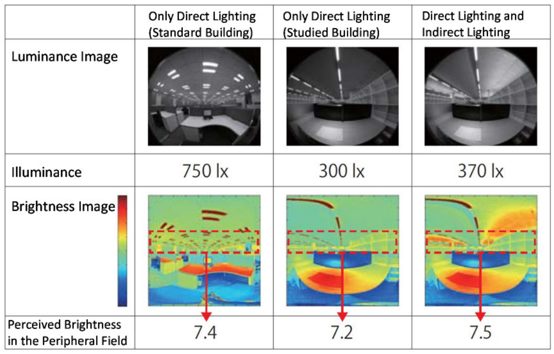

Figure 11 Comparison of Brightness Perception Calculated by Measured Brightness Image between the Studied Building and Standard Building.

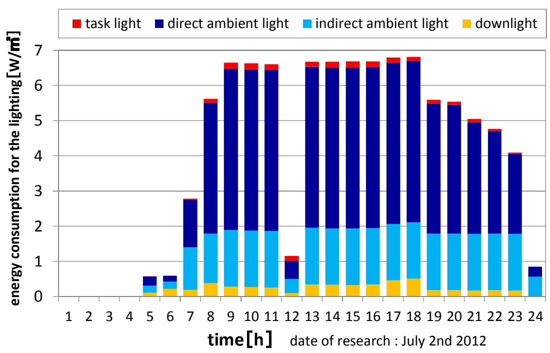

Figure 12 Measured Electricity Consumption for Lighting in the Office Space.

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position.

From the measured luminance images after completion, a brightness image was converted and the perceived brightness indicator was determined. Figure 11 shows the results of a comparison between a standard office building and this building. Compared to the standard building, the perceived brightness indicator was low when the indirect lighting was turned off. When the indirect lighting was turned on, however, the perceived brightness indicator was greater than that of the standard building, confirming that the combined use of indirect lighting would improve the perceived brightness and help to reduce overall electricity. As shown in Figure 12, the results of measurement of the electricity for the ambient system were an average of 6.6 W/m^2 at peak times. With task lighting added in, this value becomes 6.8 W/m^2, which is about half or less of electricity consumption for standard offices in Japan.

Overall Building Energy Consumption

An energy assessment was conducted to confirm the energy-conserving performance of the building. The assessment was based on the values measured during the one-year period following the completion. Figure 13 shows a comparison between the CO_2 emissions for a standard building and this building. For the standard building, the CO_2 emissions of 100 kg-CO_2/(m^2•year) for the standard office building in Tokyo in 2007 were supposed (Tokyo Metropolitan Government, 2007). The measurements from April 2012 to March 2013 amounted to 37.5 kg-CO_2/(m^2•year), representing a reduction of 62.5% as compared to the standard building. Primary energy in this building was 959 MJ/(m^2•year), a 55.2% reduction as compared to 2141 MJ/(m^2•year) for the standard office building.

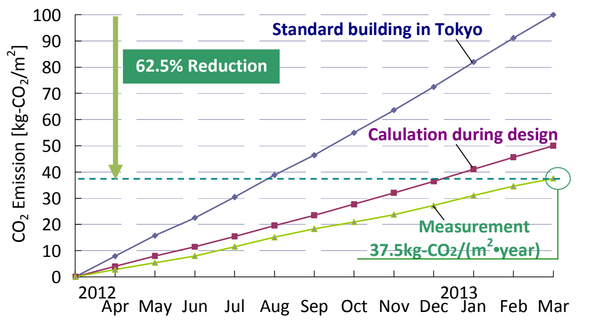

Figure 13 Measured CO_2 Emission and Predicted Value (from April 2012 through March 2013).

Figure 14 shows measured monthly electricity consumption for each item. There were few seasonal fluctuations in electricity for the server room, electrical outlets and lighting on standard floors. The seasonal fluctuations in monthly electricity were the result of fluctuations in HVAC load. Based on the results for the electricity of the HP chillers and task package systems, it was learned that the HVAC load was greater in winter than in summer. In the intermediate seasons, the electricity for Floor 3-5 office air conditioning (task packages and AHU fans) and HP chillers was low, confirming that the HVAC load was low.

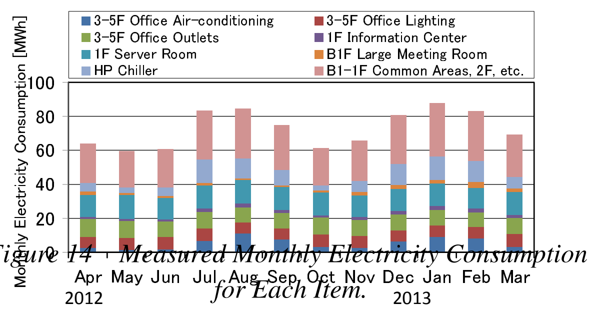

Figure 14 Measured Monthly Electricity Consumption for Each Item.

The maximum value for electricity demand was 444 kW (49.8 W/m^2), and it can be seen

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that the peak demand occurs in the winter. The average value during working hours on a working day was 18.4 W/m^2. The maximum value for lighting was 7.1 W/m^2 and the average value during working hours was 5.7 W/m^2. This value is approximately half that of an ordinary office in Japan, confirming the energy-saving performance of the lighting system introduced to this building. The maximum value for the office equipment outlets was 11.6 W/m^2, and the average value during working hours was 7.8 W/m^2, generally equivalent to the electricity of the electrical outlets in buildings with standard outlet electricity. The maximum value for air-conditioning power was 51.2 W/m^2, and the average value during working hours was 10.1 W/m^2. Wintertime electricity is great in the morning when occupants turn on the task package systems, while in summer a constant thermal load is produced throughout the day. In the intermediate seasons, the thermal load is extremely small, so in some cases the task package systems are almost completely shut down, and it can be confirmed that the electricity is low for a long time. The fact that air-conditioning electricity for the ambient AHUs and task packages is extremely low during the intermediate seasons is a major factor contributing to energy conservation in the building.

Conclusion

This paper introduced the energy-saving technologies in a low-carbon building located in Tokyo and summarized the results of performance verifications. The findings were as follows.

· Combining the ductless air-conditioning system that utilizes the Coanda effect with full flat slabs enables a ceiling-less design, which is effective for reducing resource, lowering floor height and ensuring an ample ceiling height. In addition, proper planning made it possible to prevent drafts from occurring in the occupied zones.

· For air conditioning, appropriate combination of a central system and separate package systems enables high COPs and energy conservation in all seasons.

· Planning of ambient lighting using indirect lighting based on perceived brightness made it possible to achieve lighting systems with the good light environment and reduced electricity.

· The measured CO_2 emissions were 37.5 kg-CO_2/(m^2•year), a reduction of 62.5% as compared to a standard office building in Tokyo. Primary energy consumption was 959 MJ/(m^2•year), a 55.2% reduction as compared to the standard office building.

· An analysis of electricity for lighting, electrical outlets and air conditioning revealed that lighting power and (particularly in the intermediate seasons) HVAC electricity were low, confirming that the introduced systems helped to reduce electricity.

Acknowledgment

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References

Hiromoto, S. et al. (2011). Applicability Evaluation of Air-conditioning System using a Jet Attached to the Ceiling. Proceedings of Annual Meeting of the Society of Heating Air-conditioning and Sanitary Engineers of Japan (SHASE), Japan (Japanese).

Hiromoto, S., Y. Takemasa, K. Kubota, J. Tarama, M. Sori, K. Miura, et al. (2012-2013). Plan and Workplace Environmental Evaluation of a Low-Carbon Office (Part. 1-6). Proceedings of Annual Meeting of SHASE, Japan (Japanese).

Sakata, K. (2010). Study on Environmental Brightness Index for Offices. Summaries of Technical Papers of Annual Meeting, Architectural Institute of Japan, Japan (Japanese).

Nakamura, Y. (2006). Lighting Design Using Brightness Image, 8th International Symposium on BUEE, Proc. of BUEE2006: 250- 253.

Tokyo Metropolitan Government. (2007). Energy Conservation Karte, Japan (Japanese).

Takemasa, Y., et al. (2013). Energy-saving Technologies Incorporated in Low-carbon Office Building Located in Tokyo. SB 13 Singapore: 433-440.

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The Impact of Cool Roof Applications on Energy Performance: Results from Australian Sub-tropical and Tropical Field Studies

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Abstract: *Cool roof coatings are identified by their solar reflectance index. They have been reported to have multiple benefits, the extent of which are strongly dependent on the peculiarities of the local climate, building stock and electricity network.This paper presents measured and simulated data from residential, educational and commercial buildings involved in recent field trials in Australia. The purpose of the field trials was to evaluate the impact of such coatings on electricity demand and load and to assess their potential application to improve comfort whilst avoiding the need for air conditioners. Measured reductions in temperature, power (kW) and energy (kWh) were used to develop a predictive model that correlates ambient temperature distribution profiles, building demand reduction profiles and electricity network peak demand times. Combined with simulated data, the study indicates the types of buildings that could be targeted in Demand Management programs for the mutual benefit of electricity networks and building occupants.*

Keywords: Cool Roof, demand management, peak load, solar reflectance index, tropical, load shifting

Introduction

A 'cool roof' is defined as a roof that, because of its optical and infra-red properties, usually imparted by special coatings, remains at or near ambient temperature under sunny conditions. These special roof coatings are identified by their solar reflectance and thermal emittance. A combination of these two factors is used to calculate a surface's solar reflectance index (SRI). These characteristics, combined with the thermal resistance and thermal transmittance of the roof structure, and internal and external temperatures, in essence are the key determinants of the energy balance of a roof (Figure 1) which in turn impacts on ceiling heat flux and the energy load of internal spaces [1-4] .

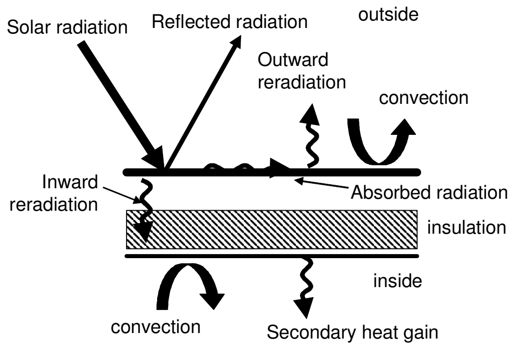

Figure 1 Energy balance of a roof (Source [1])

Previous research on the energy (kWh) and power (kW) savings and load shifting potential of cool roofs has shown that the extent of energy reductions depends on the specific climate and building typology, and that such coatings can also improve cooling equipment efficiency as well as the internal and urban environment [4-8].

The purpose of this research was to quantify the energy, power and comfort impacts of cool roof coatings on a range of building types on ten sites in tropical Townsville (latitude 19.25^{o}S) and sub-tropical Brisbane (latitude 27.5^{o}S) in Australia.

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Methodology

The field studies, conducted between 2012 – 2014, adopted a 'before and after' test protocol for fifteen residential, education and commercial buildings, as shown in **¡Error! No se encuentra el origen de la referencia.**.

Table 1 Field Study Building Specifications

#	Brief description, location and usage times	Building and Energy System Characteristics
A	School – conditioned library (1), conditioned assembly hall (1), conditioned classrooms (4 in 2 buildings), unconditioned classrooms (8 in 4 buildings) Brisbane 08:00 – 17:00 week days (M-F)	Mixture of concrete block buildings and light-weight timber buildings. Older classrooms with aged red roof and minimal ceiling insulation. Mix of refrigerative AC types, including multiple split-systems in single conditioned spaces
B1 **B2**	School - dining hall (1) 05:30 – 19:00 weekdays; 06:30 – 19:00 weekends School - administration building (1) 08:30 – 16:30 week days (M-F) Peak tariff (07:00 – 21:00 M-F) three times the cost of off-peak tariff. Townsville	(B1) Floor area 390m^2; sandwich panel roof; high level of wood framed single glazing; multiple ACs in single conditioned space (B2) Floor area 460m^2; timber framed, light weight, off ground "Queenslander" house converted into offices, most with own independent AC unit.
C	University office building (1) – three storey 09:00 – 17:00 week days (M-F)	Total floor area 3,649m^2. Concrete and breeze block construction, metal roof. District cooling system (chilled water)
D	Retail store: single storey warehouse style building with two tenancies (1occupied, 1 vacant), Brisbane 08:00 – 18:00 seven days/week	Floor area 1250m^2; flat roof Roof mounted air conditioners (96kW ducted unit per tenancy)
E	Airport terminal Brisbane Note: no Cool Roof coating applied	Floor area 55,000m^2. Light color metal roof with 200mm bulk insulation. Multiple chillers with chilled water distribution
F	Housing: single level detached (2) Townsville F1 predominantly unoccupied M-F 8am-5pm F2 predominantly occupied	Both houses on cement slab; metal roof; multiple 'single room' ACs; ceiling fans F1 conditioned area 135m^2; building efficiency - cooling load 101MJ/m^2/yr F2 conditioned area 98m^2; building efficiency - cooling load130MJ/m^2/yr

Temperature sensors (Maxim iButtons) were mounted on a shaded external location, on the roof surface, roof cavity and internal spaces. They were programmed to record temperature every 30 minutes within an accuracy of +/- 0.5°C, to provide daily temperature profiles for each building. Standard revenue meters were installed at the school sites (cases A, B), and a Dent Elite Pro XC data logger at the retail store (case D), to record half hourly electricity consumption for air conditioning loads. The BMS systems of the office and airport terminal (cases C, E) were used to monitor cooling loads (chilled water). Data from an onsite weather station and PV system at Case C was also used. Additional data was secured from local weather stations (Australian Bureau of Meteorology) and historical records (e.g. building documents, electricity bills and energy audits) where such information existed. Thermal simulations were conducted for both of the residences (case F), using BersPro 4.2, accredited software under the Nationwide House Energy Rating Scheme (www.nathers.gov.au). IES VE was used for thermal simulations of industrial and commercial spaces. Most buildings were

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coated with a Cool Roof product with a solar reflectance of 89%, the exceptions being F2 (solar reflectance 79%) and E (no coating applied). A data analysis tool (using Excel) was developed to correlate temperature and energy data. Historical weather data was used to develop daily ambient temperature profiles for each month, allowing filtering by building specific operational hours, periods of peak demand or tariff times.

Results: Impact on Temperature

Temperatures of the roof surface, roof cavity and non-conditioned internal space were recorded in all buildings (except airport) before and after the application of the cool roof coating. In the retail store, for example, the average roof surface temperature during business hours for the monitored period reduced 9ºC post coating (Figure 2). A similar reduction in internal temperature (in the vacant store) was measured. As the AC heat exchanger is roof mounted, the reduction in roof surface temperature equates to an approximate 9% increase in cooling capacity for this type of air conditioner (roof mounted ducted three phase packaged air conditioners) as well as a reduced cooling load (from reduced internal temperature).

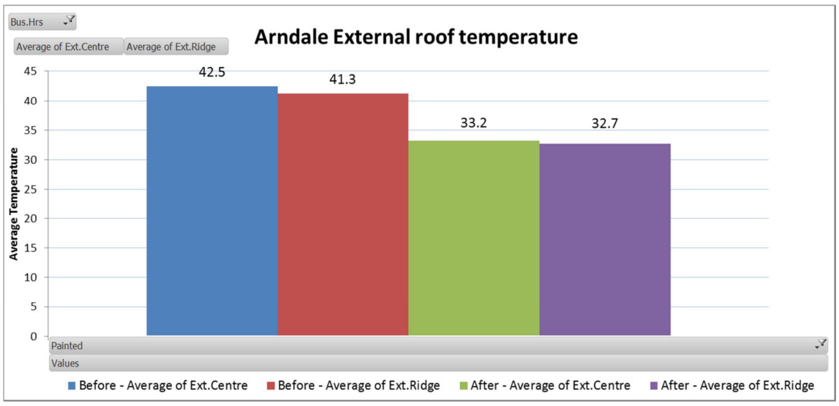

Figure 2 Reduction in roof surface temperature in retail store (Case D)

Reductions in roof surface temperatures are even more dramatic when the data is also filtered for high solar radiation days. This was done, for example, by applying photovoltaic system output data from case C to the temperature data for nearby case B school dining hall (Figure 3). As expected in a southern hemisphere tropical location, temperature reductions were greater on the western roof than on the eastern roof.

Roof cavity temperatures in the school administration building (case B2) on a hot day (34^{o}C), prior to coating, were approximately 16°C higher than ambient, compared with post coating temperatures 2-3°C higher than ambient. This is significant because high roof cavity temperatures reduce the effectiveness of ceiling insulation. The thermal resistance of bulk insulation materials on the Australian market is tested for an ambient temperature of 24°C and for temperature differentials of 18, 12 and 6K. In an air conditioned building, the temperature difference between the internal room and the roof cavity during summer may be well over 20°K. Increased temperature differences lead to increased convective currents through the insulation, further reducing their resistance to heat transfer [9].

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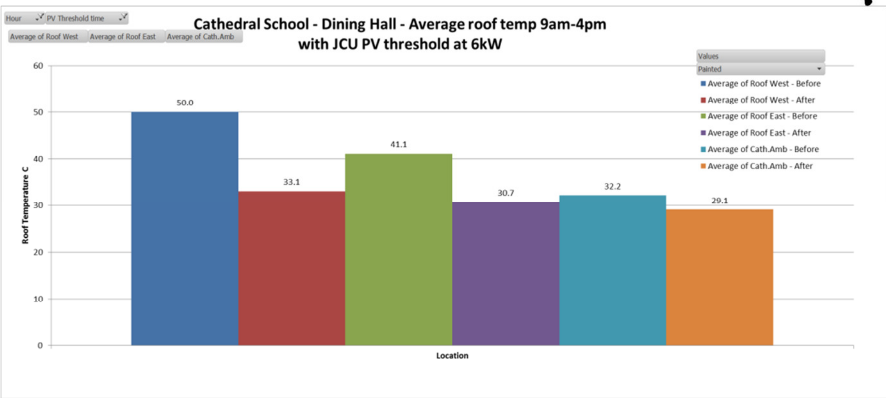

Figure 3 Reduction in roof surface temperature on high solar radiation days

In the non-conditioned classrooms, the internal temperature was monitored to quantify the impact on comfort levels in the teaching spaces (**¡Error! No se encuentra el origen de la referencia.**). These results are significant as the application of roof coatings may give schools a cheaper option for improving teaching and learning spaces, compared with the installation and operational costs of air conditioners.

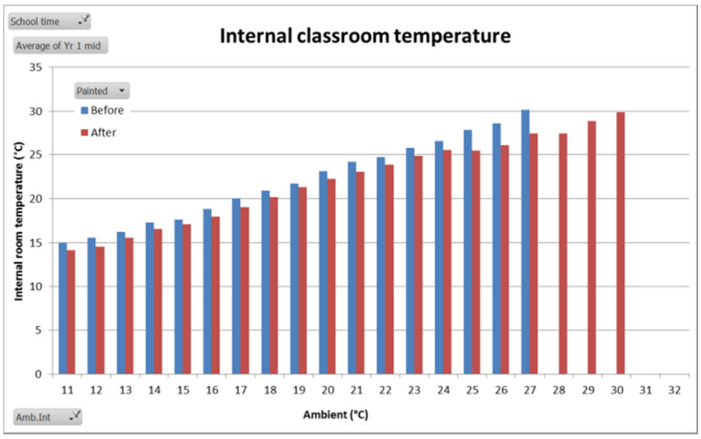

Figure 4 Reduction in classroom temperatures post roof coating

Results: Impact on Energy and Power

Cooling demand was then correlated to ambient temperature, as shown in Figure 5. All buildings showed a similar trend of great demand reductions as ambient temperature increased. Monthly temperature distributions were developed for each building (Figure 6), then applied to the building's cooling energy profile, to establish a weighted average demand for the month (kWh). The 98th percentile monthly temperature value was used to determine the monthly peak demand (kW). Before and after averages are multipled by the number of operating hours per month to arrive at the expected kWh or kW per degree of ambient temperature. Annual reductions could then be calculated (**¡Error! No se encuentra el origen de la referencia.**).

Table 2 Power and energy reductions measured in Townsville

Location	Building type	Reduction in cooling energy (kWh/m^2/yr)	Reduction in peak demand (W/m^2)
Townsville	School Dining Hall	4.95	2.8
	School Admin Building	23.00	9.1
	Office Building	27.00	9.0

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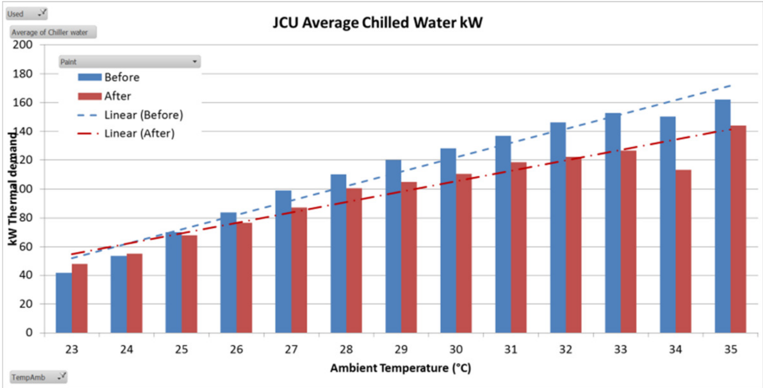

Figure 5 Trend in demand reduction by ambient temperature - office building (Case C)

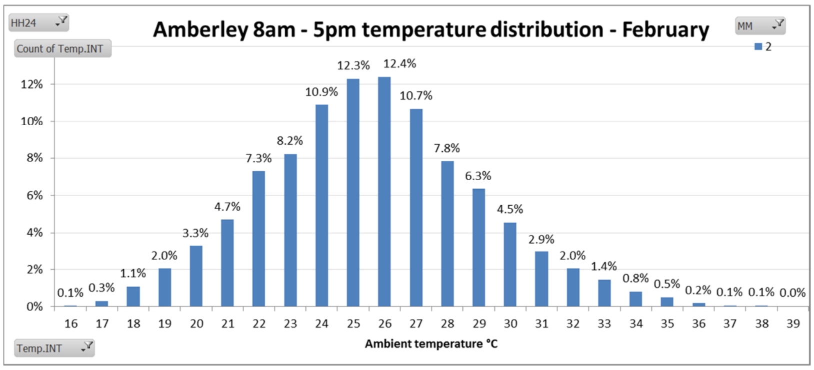

Figure 6 February temperature distribution for school hours

Discussion

The broader implications of the field study results were explored through simulation and modelling. Building simulation of one of the houses was used to show the impact that an improvement in SRI would have on the percentage of annual hours the roof cavity would be over 30^{o}C and hence impact on the effectiveness of insulation. **¡Error! No se encuentra el origen de la referencia.** clearly shows that the current building practice of installing minimal levels of insulation on the ceiling results in 35% of the year with roof cavity temperatures exceeding 36°C, compared with an ambient temperature that excedes 30ºC only 2% of the year. This simulation suggests that cool roof coatings could play a critical role in the retrofit of existing buildings, as re-coating the roof may be easier and cheaper than retrofitting reflective foil insulation, and it offers other benefits (e.g. roof restoration).

Changes to electricity tariffs may also be an incentive to consider cool roofs as an energy efficiency option. For example, the main operational hours of schools (cases A, B) occur during peak tariff times, so reducing their overall kWh/m^2 usage on hot sunny days would have significant financial benefits. Australia's housing stock is also notoriously energy inefficient [10], and the government's proposal to move residential customers to time of use tariffs in the near future may act as a catalyst for customer-driven renovations for energy

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efficiency. Simulations of thirty-seven construction variables (representing common construction types on Townsville) showed that the greatest demand reduction occured when a high SRI (90%) was applied to housing with dark and medium coloured roofs and houses with low levels of insulation. A simple equation was used for economic modelling, taking into account the cost difference between standard paints and cool roof coatings; the savings from reduced demand; the life expectancy of the coating and annual increases in the cost of electricity (10%). Combined with the data from the non-residential buildings, suggests that the electricity network could target owners of specifc building types (Table 4).

Table 3 Impact of SRI on roof cavity temperature

Changes to roof reflectivity and insulation levels			**Roof cavity T <10°C**	**Roof cavity T 10 – 19°C**	**Roof cavity T 20 - 30°C**	**Roof cavity T 31 - 36°C**	**Roof cavity T >36°C**
Ceiling insulation	Under roof insulation	Roof Reflectance	% of year the roof cavity temperature is in each temperature band				
Outdoor ambient temperature			1	15	82	2	0
R2.5	Nil	50%	2	19	44	10	25
R2.5	Nil	90%	2	20	70	7	0

Table 4 Characteristics of buildings suitable for Cool Roof Demand Management

Broad category	Specific characteristics
Spatial	High roof area to internal volume ratio
Roof reflectance	SRI less than 70
Insulation	Ceiling insulation <R3; and/or no reflective foil
Cooling system	Conventional refrigerative AC systems (not district cooling); Roof mounted air intake; High AC use (number of hours / days of year / low set point)
Electricity Tariff	Buildings with high daytime time of use tariffs and/or high demand charges

The Demand Management potential of Cool Roofs could be further explored through extension of the data analysis model developed for these field trials. More extensive data is required to enable proportional aggregation to predict customer demand response for varying times and conditions. The specific data needed includes (a) accurate local historical weather data (and arguably predicted future weather data); (b) accurate cooling load profiles for different building types within the network; and (c) regional building construction data and demographics. If this data becomes available for defined areas of interest within an electricity network, modelling would become an important factor in network demand forecasting. The different motivations of participants and the electricity networks (Table 5) would also need to be considered, to design programs with mutual benefit.

Table 5 Participant motivations for Cool Roof applications

Participant	**Motivation / Need**
Airport (Case E)	Roof needs recoating for maintenance. Can the cost difference between standard and cool roof coatings be recovered through reduced cooling demand. (Initial analysis revealed an unknown overnight cooling load that needs to be addressed first.)
Schools & Retail (Cases A,B,D)	Predominantly day time operation (high solar radiation). Want to reduce kW or kWh (depends on tariff structure) or avoid need for AC

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Office (Case C)	Invested in a very efficient district cooling system. Whilst cool roof coatings can marginally reduce demand, better financial savings can be achieved by altering the times when water is chilled.
Electricity network	Fundamental conflict between their revenue model (sell as many kWh as possible) with their need to manage infrastructure expenditure (restrain peak kW).

Conclusion

This field study adds evidence to the body of research, reinforcing the temperature and energy benefits provided by cool roof coatings in these subtropical and tropical regions. It has demonstrated the successful application of a flexible model for the evaluation of these benefits, but points to the need for more specific building and network data, and acknowledgement of participant motivations, before broader network-scale demand management programs can be developed.

References

1. Parker, D. and S. Barkaszi, *Roof solar reflectance and cooling energy use: field research results from Florida.* Energy and Buildings, 1997. **25**(2): p. 105-115.
2. Bell, J.M., G.B. Smith, and R. Lehman. *Advanced Roof Coatings: Materials and Their Applications*. in *CIB 2003 International Conference on Smart and Sustainable Built Environment*. 2003. Brisbane.
3. Gentle, A., J. Aguilar, and G. Smith, *Optimized cool roofs: integrating albedo and thermal emittance with R-value.* Solar Energy Materials and Solar Cells, 2011. **95**(12): p. 3207-3215.
4. Levinson, R., H. Akbari, and J. Reilly, *Cooler tile-roofed buildings with near-infrared-reflective non-white coatings.* Building and Environment, 2007. **42**: p. 2591-2605.
5. Synnefa, A., M. Saliari, and M. Santamouris, *Experimental and numerical assessment of the impact of increased roof reflectance on a school building in Athens.* Energy and Buildings, 2012 **55**: p. 7-15.
6. Pisello, A.L., M. Santamouris, and F. Cotana, *Active cool roof effect: impact of cool roofs on cooling system efficiency.* Advances in Building Energy Research, 2013. **7**(2): p. 209-221.
7. Bozonnet, E., M. Doya, and F. Allard, *Cool roofs impact on building thermal response: A French case study.* Energy and Buildings, 2011. **43**: p. 3006-3012.
8. Santamouris, M., *Cooling the cities - A review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments.* Solar Energy, 2014(103): p. 682-703.
9. Su, B. and R. Aynsley, *A Case Study of Roof Thermal Performance in Naturally Ventilated Houses in Hot-Humid Climates under Summer Conditions.* Architectural Science Review, 2006. **49**(4): p. 399-407.
10. Miller, W., L. Buys, and J. Bell, *Performance evaluation of eight contemporary passive solar homes in subtropical Australia.* Building and Environment, 2012. **56**: p. 57-68.

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Session 31:

Improvements by research and practice. Can the distance between theory and reality be reduced?

Chairperson:

Wadel, Gerardo
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What does built environment practice look like in the ecological worldview

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Abstract:

We are starting to see the increased impact of humanity on the environment, to the point that it is inhibiting our ability to thrive in the future. This paper builds on others pointing to the critical reason for this being the worldview currently framing how the western world sees progress and success and therefore what sustainable development means. In critiquing this approach to sustainable development the authors present an alternative: the ecological worldview. The paper will introduce what this worldview is and will analyze interviews with fifty two practitioners in the built environment who, it will be argued, are starting to practice within this worldview. Thought this process the paper will illustrate ten potential values that could underpin and guide practice in the built environment and therefore propose the framework for a potential assessment tool.

Keywords, Ecological Worldview, Regeneration, Revisioning Sustainability

Introduction

After decades of working on sustainability (and in the built environment working on sustainable, green, high performance buildings), findings from a number of recent international studies, such as the 2014 IPCC assessment report on climate change, indicate that the situation is getting worse, not better; prompting the World Watch Institute, in their 2013 State of the World report, to ask whether sustainability is still possible [1]. A key premise of this paper is that the reason we are not succeeding in reducing our impact is the framework within which we currently practice, make decisions and do our research; and that for meaningful change to occur in practice, we need to change this framework.

Our current framework structuring sustainability practice is couched in the language of quantitative, performance-based indicators reporting on performance in isolated categories, compliance with which is largely driven by individual interest: reputational, financial, or simply avoiding prosecution. Much has been written about the flaws in this framework and its foundation in the so-called mechanistic worldview, as well as the need to shift towards a more relational worldview that will help us develop frameworks suitable for working with living systems[2],[3]. This paper will not engage with this debate, but accept the need for a shift to an ecological worldview.

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By providing us with a set of narratives about how the world is created, what it is made of, how it is structured and how it functions, a worldview allows us to construct a value system that informs our ideas of what is good and true, and what constitutes ethical and effective action [4]. Murray [5] suggests that since values provide an intrinsic driver for behaviour, they may prove more influential in driving behaviour change. The purpose of this paper is to explore the relationship between built environment practice and values associated with an ecological worldview as drivers for behaviour change.

The ecological worldview and its values

The need to move to an ecological worldview in built environment practice was highlighted as early as the 1960s by Ian McHarg [6]. Since then numerous authors have explored the characteristics of the emerging ecological worldview and its main narratives [7], [8], [9]. The consensus is that the ecological worldview represents a shift from looking at the behaviour, performance and interests of individual 'parts', to considering the well-being of the whole as expressed through interdependent relationships - a web of life of which humans are irreducibly part. This understanding is reflected in the growth of built environment practices that not only aim to re-integrate humans and nature, but see humans as active participants in the co-creation of the living systems we inhabit. Further that we have a responsibility to support the health of these systems and nurture their evolutionary potential – for example, some biomimicry approaches, biophilic design, and regenerative development and design. The second key aspect of this worldview is the understanding that living systems are characterized by change, and therefore uncertainty and unpredictability. To thrive in a world that is in constant change it is important to build resilience into the social-ecological systems; that means moving away from only efficiency, control and conservation to adaptive management and increasing diversity and redundancy.

From the core meta-narratives of wholeness and change within the ecological worldview, themes of interconnection, interdependence, co-creation and co-evolution, change, unpredictability and integration, emerge to define a value system based on how nature works [4]. Values can be defined as "expressions of, or beliefs in, the worth of objects, qualities, or behaviours" that "define and direct us to goals, frame our attitudes, and provide standards against which the behaviour of individuals and societies can be judged" [10]. It must be noted that there is a large body of research dealing with environmental/ecological values and ethics [5], [11], [12], [13]. The ten values identified in this paper draw on some of this work, but also flow from a simple question:

> *What would be the appropriate values for an interdependent, constantly changing and unpredictable reality in which our main goal is the continued well-being and healthy functioning of the whole?*

These values can be organised into three categories. The first set of values derives from an understanding of wholeness anchored in the idea of an interconnected, interdependent and integrated world. The corresponding values are Integrity and Inclusivity. The second set of values relates to the importance of positive and mutually supportive relationships, leading to the values of Mutuality, Fellowship, Positive Reciprocity, Responsibility, Respect and Harmony. The third set of values arises from accepting that the world is constantly changing, inherently unpredictable and ultimately impermanent, leading to values of Humility and Non-attachment. Critically, these ecological values shift us from a centric basis of assigning value (whether anthropocentric or eco-centric) to a relational basis of valuing [13].

Methodology

Between 2011 and 2014, fifty two people were interviewed across a range of architects, designers, engineers, builders, developers, development facilitation consultants, entrepreneurs, sustainability directors, ecologists, project and building managers and academics. These were identified based on their contribution within the literature and built environment (e.g. were published in highly ranked journals, or were responsible for buildings with high green ratings, such as LEED platinum or Living Building Challenge), or were well known in the industry for their regenerative and innovative work. Each interview lasted at least an hour; many included hours of site visits to projects that embodied the practice of those interviewed. Interviewees were asked to describe their practice, its challenges and its successes in attaining high levels of ecological sustainability, as well as contribution to ecosystem service creation or regeneration, and the development of social good.

Preliminary qualitative content analysis was used, as it allows for a purposefully selected sample to investigate a phenomenon or research question rather than random sampling required in quantitative content analysis [14]. This approach allowed for “qualitative data reduction and sense-making effort that takes a volume of qualitative material and attempts to identify core consistencies and meanings” [15], allowing the identification of themes and patterns with in the interviews that corresponded with the narratives and values of the ecological worldview. Called *directed content analysis* this is an approach: “in which initial coding starts with a theory or relevant research findings. Then, during data analysis, the researchers immerse themselves in the data and allow themes to emerge from the data. The purpose of this approach usually is to validate or extend a conceptual framework or theory.” [14]. In simple terms, the interviews were analyzed for key words and themes as they illustrated the applications of the ten values of the ecological worldview outlined above.

Results and discussion

This discussion will be structured according to the three categories of values identified above.

The values of wholeness – Integrity and Inclusivity

The research looked for evidence of projects contributing to the maintenance of the structural integrity (its intactness) and functional integrity of the system in which the project was placed, as well as is adherence to an internally consistent framework of principles defining the larger system’s identity. Evidence for this was found in the way most practitioners looked at the project as an interconnected part of a bigger system, and at how the project can contribute to this system. For example, the Omega Centre for Sustainable Living, designed by BNIM,

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not only treats the sewage from the local campus but also treats water from a local lake improving the water quality going into the Hudson River and provides wetlands for ecosystem services, such as habitat, oxygen production, water treatment and so forth. The Story of Place™ process used by Regenesis enables the project to be integrated into the larger system in a way that aligns with the principles defining that system's identity.

For the value of Inclusivity, the analysis looked for evidence that the practitioners aimed to interact with the world in its entirety. That is, evidence that there was an integration of humans and nature, the different dimensions of existence (matter, mind, life, and spirit), different hierarchical levels, as well as different domains of knowledge and ways of knowing. It was found that the practitioners, using charettes, workshops and even social media, collected information and input not only from those who commissioned the work but all the stakeholders involved: community, professionals and nature (through ecological, geological and hydrological studies). Several groups developed tools to support this process by visualising the relationships between all these sources of knowledge and the opportunities thus revealed. The processes used allowed all parties to contribute to the development of the core principles of the project.

It was found that the values of inclusivity and integrity are also expressed in the personal lives of the participants who were seen to consciously integrate the interior (values, beliefs, and ethics) and exterior (behaviour) aspects of their lives. Pamela Mang explained that the need for pursuing also personal 'wholeness' can be attributed to the realization that "the main hazards we face in the world arise from our tendency to get fragmented, to not be able to be an integrated human being,… [from] our inability to see ourselves in a context and in a relationship that's a reciprocal relationship" [16].

The values of relationship – Harmony, Respect, Positive Reciprocity, Responsibility, Fellowship and Mutuality

The ecological worldview emphasizes the importance of relationship as the main creative principle in that everything that exists is the product of relationships created through exchanges of energy, matter, information, or emotion. The qualities and quantities of these exchanges can strengthen or weaken the entire network of relationships, which is why values such as Harmony, Respect and Positive Reciprocity (reciprocating in a way that is of benefit to and advances the relationships within the network or system) are important foundational aspects of practice in the ecological worldview. Evidence for these values could be found in the facilitation processes used by most of the practitioners that aim to drill down to values common to all stakeholders and develop a shared understanding of the place (the social-ecological system) within which the project is situated; and from there develop a vision that allow the expression of these common values in a manner that is in integrity with the identity of the place, and that contributes positively to the health, well-being and future evolution of the place.

It was also found that those interviewed felt they were in an active and co-operative relationship with the world which requires that they act as responsible members of the community of life, and holds them morally accountable for the consequences of their actions. This corresponds to the values of Fellowship and Responsibility. Not only do they experience this sense of fellowship through their projects, but also as members of a community of practice co-creating the paradigms of the ecological worldview. As Bob Berkebile explains:

> "*What I am seeing now is a new sense of community… and a new sense of what can we do together that we didn't accomplish with our separate competitive green ideas.*" [17]

A further characteristic of the ecological worldview is an extended awareness of the self as part of an interconnected whole that is also part of the self, giving rise to the value of Mutuality, which represents the idea that we are in this together, and what happens to the 'other' will also have an effect on the self [13]. It is the root of practices such as compassion, which aims to consciously place oneself in the shoes of the other, and to treat others as one would treat oneself – with care and respect. This sense of compassion and being open to the experiences of others, while sharing one's own vulnerability, is one of the most remarkable characteristics of the research subjects. The ability to be open and share who you are is essential to facilitation work that aims to find the common values between disparate parties and allow them to connect through their common humanity. As one construction project manager explained:

> *Where you're bringing in the values, you're connecting with story, and it's less about agendas and it's more about your heart…And you can't find that stuff until you start sharing yourself.* [18]

This openness is reinforced by the next set of values – those supporting action in a changing world.

The values of change – humility and non-attachment
The ecological worldview describes a world which is not fixed, but an ever-fluctuating process of change and transformation, and in which we cannot know the true consequences of our most well-intentioned actions. As Bill Reed states: "We don't know enough to think our way out of this [global situation]. And therefore we have to be humble and open to the present as well as the potential." [19] Therefore to be effective in this world, the value of humility is crucial to counteracting the hubris of the 'expert' and encouraging reflective practice – that is, "the capacity to reflect on action so as to engage in a process of continuous learning"[20].

One of the most interesting findings to emerge from the interviews was the iterative relationship between changing practice and personal transformation experienced not only by the practitioners, but also by their clients and the communities within which they were working. As one of the architects who worked on the Omega Centre recounts: "I don't think anybody who worked on that project wasn't transformed in some way" [21]. She further describes how the project continues to have a ripple effect, touching and changing "every contractor, every person who teaches there, every person that visits there".

Possibly the most difficult aspect of the ecological worldview to accept is the realization of our own impermanence and of the impermanence of all around us. Second is the realization that we cannot control everything and therefore have to act "with a certain amount of humility and recognition that you're likely to fail" [22]. Responding to this is the value of non-attachment - realizing the futility of trying to hold on to anything in an ever-changing world, including ideas, dogmas and strategies [23]. Attachment to ideas and outcomes limits one to the possibilities in hand, and thus reduces the ability to adapt to changing circumstances or to recognize the potential opportunities [13]. The post-disaster reconstruction work done by BNIM consistently emphasized the opportunity that lies in disaster for moving past old constraints and creating a better future, as for example the town of Greensburg, Kansas which used the devastation brought by a tornado to reinvent their town as the greenest town in America.

Developing the values of humility and non-attachment also allows both the practitioner and client to firstly let go of the need to be in absolute control of the outcome and secondly, to let go of a design, an idea, a concept, or a solution that may not be in the long term interest of the larger system, or does not present opportunities for multiplier solutions which will address multiple opportunities and problems simultaneously [4]. Furthermore, letting go of the need to build the most 'sustainable' object, allows the practitioner to start asking how the process of creating the object can become a catalyst for developing the potential of the larger system. One of the landscape architects interviewed highlighted this need for non-attachment.

> *"So one of the biggest transformations I've had to make in doing this work is to be unattached to the physical manifestation of the project, and to learn to look beyond that to what is actually really being developed, that maybe is more necessary to develop to have ramifying impacts in the world."* [24]

Conclusion – the glimmer of a values-based diagnostic tool for the built environment

The research found many examples of how the values that underpin the ecological worldview are expressed in practice. Unfortunately space constraints prohibit a full discussion. Apart from suggesting a number of lessons for practice that would support the building industry in adopting a more holistic and integrated approach to development, a further outcome of the research was the emergence of a values based diagnostic tool for built environment practice. A tool that is supportive of the sustainability objectives of the ecological worldview. One of the strongest critiques against current assessment and rating tools is their failure to ensure that projects are not only resource efficient, but also uphold the values of sustainability. The result is often superficial lip-service with little positive impact on the larger system. It is proposed that introducing a values-based tool will encourage the development of built environment projects that have the potential to bring about the kind of far-reaching social transformation that is necessary if humankind is to not only meet the challenges of the 21st century, but use the opportunities brought by these changes to create a thriving and regenerative world.

References

[1] World Watch Institute (2013). State of the World 2013: Is Sustainability Still Possible? Washington, DC: Island Press.
[2] Rees, W.E. (1999). Achieving sustainability: reform or transformation? In D. Satterthwaite (ed.) *The Earthscan Reader in Sustainable Cities*, Earthscan, London, pp. 22–52.
[3] Du Plessis, C. and Cole, R.J. (2011). Motivating stakeholders: Changing the paradigm. *Building Research and Information*, 39(5), pp. 436-449.
[4] Hes, D. and Du Plessis, C. (forthcoming 2015) *Designing for Hope: Pathways to regenerative sustainability*. London: Earthscan by Routledge.
[5] Murray, P. (2011). *The Sustainable Self: A Personal Approach to Sustainability Education*. London: Earthscan.
[6] McHarg, I. (1969). *Design with Nature*. New York: Natural History Press.
[7] Goldsmith, E. (1988). The Way: An ecological worldview. *The Ecologist*, 18:4/5. Accessed 29/01/2008 from http://www.edwardgoldsmith.com/page138.html.
[8] Capra, F. (1997). *The web of life*. London: Flamingo.
[9] Elgin, D. & Le Drew, C. (1997). *Global consciousness change: Indicators of an emerging paradigm*. California: Millennium Project.
[10] Leiserowitz, A. A., Kates, R. W., & Parris, T. M. (2004). Sustainability values, attitudes and behaviours: A review of multi-national and global trends. *CID Working Paper* No.113. Cambridge, MA: Science, Environment and Development Group, Centre for International Development, Harvard University.
[11] Sterling, S. (2003). *Whole systems thinking as a basis for paradigm change in education: Explorations in the context of sustainability*. Unpublished doctoral dissertation. Bath, UK: University of Bath.
[12] Doppelt, B. (2010). *The Power of Sustainable Thinking*. London and New York: Earthscan.
[13] Du Plessis, C. (2013). Using the long lever of value change. In Crocker, R and Lehmann, S. (eds.) *Motivating Change: Sustainable Design and Behaviour in the Built Environment*, Oxon, UK: Routledge Earthscan series. Pp. 92-108.
[14] **Zhang, Y.** & Wildemuth, B. M. (2009). Qualitative analysis of content. In B. Wildemuth (Ed.), *Applications of Social Research Methods to Questions in Information and Library Science*. Westport, CT: Libraries Unlimited. pp.308-319.
[15] Patton, M.Q. (2002). *Qualitative Research and Evaluation Methods*. Thousand Oaks, CA: Sage, p. 453.
[16] Pamela Mang, personal communication, 17 September 2012.
[17] Bob Berkebile, personal communication, 6 September 2012.
[18] April Brown (née Wackerman), personal communication, 12 September 2012.
[19] Bill Reed, personal communication, 3 September 2012.
[20] Schön, D. (1983). The Reflective Practitioner, How Professionals Think in Action. New York: Basic Books.
[21] Laura Lesniewski, personal communication, 06 September 2012.
[22] Ben Haggard, personal communication, 17 September 2012.
[23] Batchelor, M. (2001). *Meditation for life*. London: Frances Lincoln.
[24] Joel Glanzberg, personal communication, 17 September 2012.

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Compact Cities for a Fast Urbanizing World

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Abstract: *The world will add 2 billion new urbanites within next 20 years. Urban surfaces will more than double. In a business-as-usual scenario, this massive urban growth will happen at 95% as edge and leapfrog sprawl, with considerable pressure on the environment, loss of arable land and of economic productivity of land-use, social fragmentation and segregation. It will be the main driver of climate change. Reshaping developing countries urbanization trajectory towards mixed-use, compact and connected urban forms is the most effective way to mitigate climate change and, compared to only technological solutions, has multiple co-benefits: reduce congestion and pollution; reduce the cost of infrastructures; increase land use productivity and economic competitiveness, reduce pressure on agricultural land and natural resources; reduce social segregation and create a more inclusive society.*

Keywords: Compact cities, Urban development, Urban policy

Introduction
According to the United Nations, the world reached an invisible milestone in 2008: for the first time in history, more than half of humankind, 3.3 billion people, was living in urban areas. By 2030, this is expected to swell to almost 5 billion, 60% of the world population. Most of this urbanization will be taking place in emerging and developing countries, at twice the OECD countries pace. The urbanization rate will be the highest in African and Asian small cities, but the population living in megacities (more than 10 million inhabitants) will rise from 9% to 12% in 2025, from 19 megacities today to 27 [1]. Along with the growth of the urban population, the urban area increases at a much faster pace. More than 58,000 km² were urbanized from 1970 and 2000, an area equivalent to 1.3 times the size of Denmark [2]. During the 1970-2000, the urban area increased 1.5 times faster than the population in most cities in emerging and developing countries: in almost all Chinese cities, Madagascar (Antananarivo), South Africa (Gauteng), Mexico (Guadalajara and Mexico City) or Egypt (Cairo). China's urban population grew by 45% from 2000 and 2010. During the same period, the urban area increased by 93% in Guangzhou, 97% in Chengdu and more than doubled in Shanghai, Hangzhouo, Hefei, Quanzhou, Fuzhou, Baoding and Nantong [3].

Projections indicate a doubling of the global urban population between 2000 and 2030, with at the same time a tripling of the urban built area, from 200,000 to 600,000 km², leading to a drop by almost 1/3 in the average urban density [4]. Average urban densities decline sharply in both developed, emerging and developing countries. The most significant declines occurred in developing and emerging countries. For example, the average density of Chinese cities was divided by two in twenty years. If Guangzhou had the same density profile as Seoul, it could host 4.2 million additional residents, or 70% more [3].

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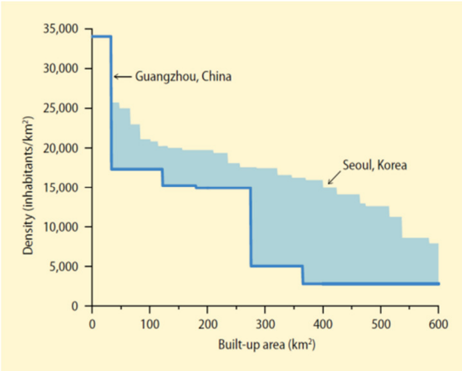

Figure 1: Density profiles in Seoul and Guangzhou [3]

Urban sprawl and fragmentation - Climate, Economy & Social consequences

Urban sprawl significantly contributes to climate change. Cities consume the majority of global energy production (between 60 and 80%) and account for a similar share of carbon emissions [5]. Sprawled and fragmented urban forms have a very high per capita carbon emissions and energy consumption. The first reason relates to transportation: low density and fragmentation induce higher average distance travelled, and up to 10 times higher per capita energy consumption. When comparing a dense city like Paris intramuros or Manhattan (aroung 20,000 inhab/km²), and a city with low density (5,000 inhab/km² on average in Chinese cities), transport emissions per capita are multiplied by 2.5. They are multiplied by a factor 10 for an even more sprawled city (2,500 hab/km²) [3]. Urban sprawl, which often rhymes with isolated and scattered buildings, also induces higher energy consumption for buildings, especially for heating. Japanese cities are on average 5 times denser than Canadian ones, and the primary energy consumption per capita is 40% lower. This comparison holds when choosing countries with similar climatic contexts and heating needs: Danish cities are on average 4 times denser than Finnish cities and consume on average 2.5 times less primary energy per capita [5].

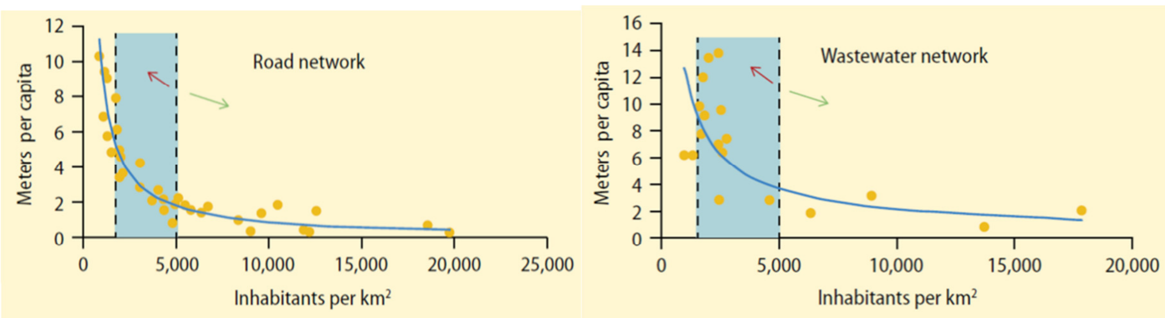

Figure 2: Per capita infrastructure costs and urban density [3]

Urban sprawl results in additional costs to the community as it involves over-sizing of infrastructure networks. The cost of automobile dependence related to urban sprawl in the United States is estimated at $ 184 billion per year, without taking into account the costs of congestion and loss of tax revenue due to the space used for traffic and parking [6]. When comparing a dense city like Paris or Manhattan intramuros, 20,000 inhab/km², and a low density city (5,000 inhab/km²), per capita infrastructure costs increase sharply [3].

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- Times 4 for the road network
- Times 3 for the waste water network
- Plus 40% for the water network

Houston is 6.5 times less dense than Madrid. Per capita infrastructure costs are 5.6 times higher than in Madrid, and private car use is 3.3 times higher. GDP carbon intensity is 30% lower in Madrid (190ktCO2e/US$bn, 263 in Houston) and per capita carbon emissions are twice lower (6.9 to 14.1 tCO2e/cap in Houston). Urban sprawl degrades economic productivity. Agglomeration economies that make cities more productive and successful directly relates to city compactness. Concentration of activities in compact cities allows for faster trade and lower transaction costs for goods, services and information. Compact cities, by bringing closer together the people, goods, services, materials and markets, by focusing talent and facilitating interactions and exchanges, create a myriad of opportunities, improve productivity, and foster innovation. The collapse of urban density in Chinese cities (divided by 2 in 20 years) is causing a collapse of land productivity, as shown in the following graph, which displays GDP/km² in 2000 and 2010 in 13 Chinese cities. In a decade, Chinese cities' land productivity was divided by 9 on average, and up to 50 in cities like Ningbo [3].

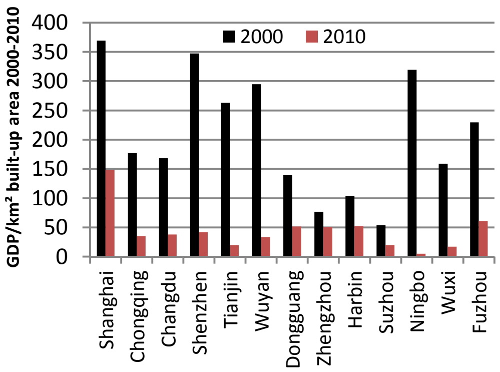

Figure 3: Collapse of land productivity in Chinese cities between 2000 and 2010 [3].

Urban sprawl is a barrier to social inclusion because of car dependency and infrastructure costs. Low urban densities and urban fragmentation induce car dependency and directly impact on household budgets. Individual motorized transportation is 98% dependent on fossil fuels. It has therefore has an extreme sensitivity to oil prices. Americans work 2 hours each day in average to pay for their car. In the United States, the budget devoted to transportation between a household living in a compact urban development (with a high density of employment and close access to services and urban amenities) and the same household (in terms of income and composition) in a low density suburb increases by 80%. In California and Florida, the estimated additional cost of urban sprawl is US$20,000 per dwelling unit [6].

In China, low compactness and urban fragmentation generate significant congestion problems. In Beijing, a resident loses RMB335 per month on average (12.5% of average income) because of congestion. In Shanghai, the loss of income due to congestion is around 9%. In South Africa, the most vulnerable households spend more than 50% of their income to commute, even without taking into account the time lost in transport, which can reach 4-5

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hours for these populations. The drop in value of South African Rand (-20 % in 2013 compared to US$) induced an increase in gasoline pump price of 14% in 2013. A similar increase in 2014 would increase the budget dedicated to transport of the most vulnerable populations from 50 to 57%. Per capita infrastructure costs are up to 5 times higher in sprawled cities compared to compact cities. In developing countries, these additional infrastructure costs contribute to the increase in informal housing, without access to essential infrastructure. According to UN- HABITAT, over 900 million people will be living in slums in 2020, with limited access to water, sanitation and electricity. Urban sprawl, by extending physical distances to jobs and putting a strain on the budget of the most vulnerable households, is a spatial poverty trap that is characterized by a high rate of unemployment, poor living conditions, social exclusion, lack of social interaction and a high crime rate [7]

Energy efficiency, economic growth and social inclusion reinforce and are simultaneously achieved by compact urban forms

Compact cities are not only dense cities, but display the following characteristics:

- High intensity (residential density, employment, activities, services, trade and interactions)
- Strong functional, economic and social diversity on the district and block scale
- High accessibility to services and urban amenities: health, education, shops, culture, green and public spaces.

Urban development intensity and diversity provide greater accessibility to jobs and essential services, which contributes to the decreasing average distance traveled, and therefore energy consumption and emissions. Articulating urban planning and transport infrastructures supports faster and lower cost deployment of sustainable transport modes. Individual motorized transport is highly dependent on fossil fuels (98%). Low urban compactness prevents modal shifts to public transport. The following graph displays the required population density (inhabitants and jobs per km²) to make public transport investment economically profitable. Bus Rapid Transit systems (BRT) require a population density of 10,000 people/km² on average. Light rail transit (LRT) requires 15,000 people/km² on average and heavy rail (HR) 20,000 people/km² [8].

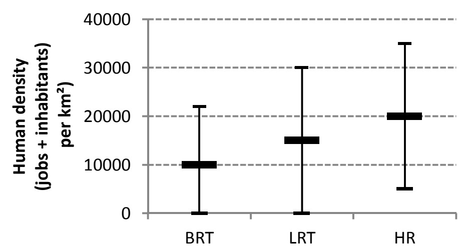

Figure 4: Density thresholds to ensure economic profitability of public transport investment. The price range for each mode reflects construction costs in different countries (adapted from Guerra and Cervero, 2011)

The second reason relates to access. One of the key drivers of modal shifts towards public transportation is station accessibility. The share of the city dwellers living within 500m of a station is one of the major determinants of the modal share of public transport. Great accessibility to public transport networks is made easier in compact urban areas. For subway networks of similar size, the coverage ratio varies very significantly:

- Paris : 219km and 302 stations, 100% of residents within 500m of a station
- Manhattan: 337km of lines and 422 stations, 100% of residents within 500m of a station
- Beijing (inside the 2nd ring road) : 456km and 270 stations, only 44% of residents within 500m of a station

Poor access to public transport in non-compact cities like Beijing or Shanghai is one of the causes of congestion, and contributes to their high energy intensity: they require 6 times more energy as London, Hong Kong, Paris, Seoul or Tokyo to produce one unit of GDP [9]. Optimizing public transport accessibility requires articulating urban planning and transport infrastructure. In Seoul, Floor Area Ratio (FAR) is set with a very fine grain zoning and adapted to transport infrastructure capacity: 10 in the heart of CBD, 8 in the rest of CBD and in sub-centers, between 0.5 and 5 in residential areas, with peaks around transit hubs. In Manhattan, FAR regulations are detailed on the block scale: 15 in the CBD, 10 along main avenues and near the CBD, and between 0.6 and 10 in the rest of the city.

Compact and mixed-use urban forms contribute to energy peak shaving and facilitate the deployment of synergy strategies. More compact urban forms can divide by more than two energy demand, both in the field of transport and thermal comfort. But greater compactness and greater mixed use also helps to shave local energy peaks and facilitates the deployment of synergy strategies. Mixed use, by bringing closer buildings with different energy demand profiles (eg offices and housing) allows under certain conditions to reuse energy flow (eg heat flow) that would have been lost otherwise. The deployment of these strategies, which requires both high density and mixed use, can reduce energy demand by up to 40% [10].
Compact urban forms increase economic productivity. The high compactness of New York City Core, and Manhattan in particular, contribute significantly to the vitality of the local economy. A New Yorker travels on average 9 miles a day, against 25 in average for an urbanite of another US large urban area, which is a 23 million tCO_2 saving each year across the city. Spending less time in their cars, New Yorkers save US$19 billion gasoline every year compared to the average US city. Rather than feeding trade deficit, this amount is reinjected back into the local economy [11]. Across the U.S., 50% of the variation in economic productivity per capita can be explained by job density. A doubling of employment density in U.S. cities corresponds to a 6% increase in hourly labor productivity [12]. A study including 261 Chinese cities shows that economic productivity in China increases by 8.8% with a doubling of employment density [13].

Local authorities financing schemes must be questioned to slow down land grabbing. Urban sprawl and land grabbing encroaches on farmland and jeopardizes environmental resources nearby cities. Only strict regulations are likely to curb the rate of land grabbing, which is explained by large price differences between rural and urban land. In Hong Kong, banana and orange crop are the most profitable activity on rural land, with approximately US$240,000 a year. In comparison, converting and selling 1km² rural land into urban land generates US$80 million, an amount likely to provide an annual income of $4.8 million with a 6% interest rate, which is 20 times more. If reinvested in residential or industrial development, it could generate up to 20% per year. During the speculative phase of 90s Hong Kong, some lands have generated an annual return of over 50% in the residential real estate market. In mainland China, this process is widely used by municipalities and local authorities for financing themselves. In Guangzhou in 2006, 55% of municipal finances originated from land sale, up to 80% in Shenzhen in the 90s [14]. One strategy to control urban expansion rests upon reforming local taxation regulations, in particular through property tax reforms. Split-rate property taxes, which apply a lower rate on land than on buildings, promote more compact urban development. This strategy has been successfully used in Sydney, Hong Kong, Pittsburgh, and in several Chinese cities. Another strategy consists in increasing tax rates with the distance to urban core (Austin), or to set a lower rate for collective housing than for individual housing (Denmark, Switzerland). Finally, taxing sub-density (France) makes it possible to penalize new urban developments below a given threshold of density.

Land Value Capture (LVC) is a key financing scheme for infrastructures and urban development. The notion of Land Value Capture (LVC) is to "mobilize for the benefit of the community at large some or all of the land value increments (unearned income) generated by actions other than the landowner's such as public investments in infrastructure or administrative changes in land use norms and regulations"[15]. LVC instruments can be classified into two major categories: "Tax- or Fee-based" LVC instruments and non-tax based, referred to as "Development-based" LVC (DBLVC) instruments [16]. DBLVC instruments capture land value increments through various public-private transactions such as land and land use rights sales, air and underground rights sales, land readjustment, and urban redevelopment financing schemes. DBLVC schemes being practiced in selected cities across the world, like Hong Kong SAR, China, Tokyo, Japan, London, United Kingdom, and Washington, DC, USA, allow them not only to generate funds for transit investment and operational and maintenance costs, but also promote sustainable urban development through TOD. If adapted well to local contexts, DBLVC schemes have great potential to become an important strategic apparatus of urban finance and planning for cities in developing countries ((Suzuki et al., 2014). From 1980 and 2005, using DBLVC, Hong Kong government received about US$22 billion from land premiums, market capitalization, shareholder cash dividends and initial public offer proceeds, while injecting about US$4 billion equity capital.

Conclusion

Urban sprawl and fragmentation, both in developed, developing and emerging countries, contributes significantly to carbon emissions and climate change. But this trend also has negative impacts in terms of economic productivity and social inclusion: increase in per capita infrastructure costs, lower land productivity, car and fossil fuel dependency, and energy precariousness for the most vulnerable households. To counter this trend, with more than 60 million new urbanites expected each year, a range of regulatory and financial instruments could support and foster the emergence of more compact, accessible, connected and mixed urban forms. These strategies will contribute to climate change mitigation, but at the same time to economic growth and social inclusion.

References

[1] UNFPA, "State of World Population 2007 - Unleashing the potential of urban growth," 2007.

[2] K. C. Seto, M. Fragkias, B. Güneralp, and M. K. Reilly, "A Meta-Analysis of Global Urban Land Expansion," *PLoS ONE*, vol. 6, no. 8, p. e23777, Aug. 2011.

[3] World Bank, International Bank for Reconstruction and Development, and Development Research Center of the State Council, P.R. China, "Urban China: Toward Efficient, Inclusive, and Sustainable Urbanization," Washington D.C., 2014.

[4] UN Habitat, *Secure land rights for all*. Nairobi: United Nations Human Settlements Programme, Global Land Tool Network, 2008.

[5] L. Kamal-Chaoui and A. Robert, "Competitive Cities and Climate Change," OECD Publishing, OECD Regional Development Working Paper 2009/2, 2009.

[6] S. Osman, A. Nawawi, and J. Abdullah, "Urban Sprawl and Its Financial Cost: A Conceptual Framework," *Asian Social Science*, vol. 4, no. 10, pp. 39–50, Oct. 2008.

[7] U. Grant, "Spatial inequality and urban poverty raps," ODI Working Paper 326, 2010.

[8] E. Guerra and R. Cervero, "Cost of a Ride," *Journal of the American Planning Association*, vol. 77, no. 3, pp. 267–290, 2011.

[9] GEA, *Global Energy Assessment - Toward a Sustainable Future*. Cambridge, UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria: Cambridge University Press, 2012.

[10] Rotterdam Energy Approach and Planning, "Towards CO2-neutral urban development," REAP, Rotterdam, 2009.

[11] J. Cortright, "New York City's green dividend," *CEOs for Cities*, 2010.

[12] F. Haughwout, "How Should Suburbs Help Their Central Cities? Growth and Welfare-Enhancing Intrametropolitan Fiscal Distributions," *Annals of The American Academy of Political and Social Science - ANN AMER ACAD POLIT SOC SCI*, vol. 626, no. 1, pp. 39–52, 2009.

[13] J. Fan, "Industrial agglomeration and difference of regional productivity," *Front. Econ. China*, vol. 2, no. 3, pp. 346–361, Jul. 2007.

[14] O. Merk, S. Saussier, C. Staropoli, E. Slack, and J.-H. Kim, "Financing Green Urban Infrastructure," OECD regional development working paper 2012/10, 2012.

[15] M. O. Smolka, *Implementing value capture in Latin America: policies and tools for urban development*. Cambridge, MA: Lincoln Institute of Land Policy, 2013.

[16] H. Suzuki, J. Murakami, Y.-H. Hong, and B. Tamayose, "Financing transit with land values," World Bank, Urban Development Series, 2014.

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Breaking symmetries and emerging scaling urban structures

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Abstract: *Mathematical regularities emerge in resilient cities like in all natural living phenomena. They come from the scale-free properties of complex systems that present the same level of complexity across their different scales. They take the form of inverse power laws that are the « signature » of complexity. In living cities, these mathematical regularities derive from historical layering over millennia (Paris) or from intense market forces (New York). In complex, living and resilient cities, the distribution of elements and connections does not obey Gaussian laws (concentration around averages) but scale-free inverse power laws (Pareto laws). Understanding the universality of this structure which also characterizes natural phenomena and living systems, and which has been violated by modernist city planning, would allow planning more efficient and resilient cities. The paper shows how initial breaks of symmetry fostered the emergence of scale-free structures in Paris and New York, with long-range time correlations.*

Keywords: Urban form, Complexity, Platting, Scaling, Manhattan, Paris

The challenge of a new science of cities: is the urban world Gaussian or Paretian?

The challenge of a new science of cities is to understand the links between urban morphogenesis, efficiency and resilience. It is also to understand the relationships between self-organization and planning. The large number and diversity of agents operating simultaneously in a city suggest that cities are a multi-fractal emergent phenomenon. On the other hand, planning plays an important role in the city, leaving long standing traces, and could be thought of as an external perturbation, as if it were foreign to the self-organized development of a city. Fractal geometry and complex systems theories reveal mathematical regularities maintained through the seemingly chaotic process of urban change. Fractal geometry has contributed to climate modeling, to study turbulent flows, to analyze brain waves and seismic movements as well as to understand the distribution of galaxies. It has also transformed finance by revealing a hidden complex order in the seemingly chaotic fluctuation of prices. It should transform the study and planning of cities. Historical cities display a multi-fractal structure layering and interlocking different fractal structures belonging to different morphological periods; the fractal and scaling parameters display high local variations (singularities) which are organized in fractal sets (isohölder) described by a spectrum of fractal dimensions (Haussdorf spectrum).

In other words, are averages (average density, average GDP, average energy intensity or GHG emissions) meaningful in urban studies? In a Gaussian world they are meaningful because 68% of the values are at one standard deviation from the average. Quite the opposite, a

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Paretian world is extremely unequal: a few extremely high values are juxtaposed to a “long tail” of very low values.

Two different kinds of symmetry: modernist planning translation symmetry versus historical scaling symmetry

Symmetry plays a fundamental role in physical phenomena. Symmetries are certain properties of laws of physics that are conserved when a system undergoes a given geometric transformation. Equations in physics are, for example, invariant by translation in space and time. From this perspective, fractal geometry corresponds to a form of symmetry that is dilatation symmetry or scale invariance. It is found in countless natural phenomena and in living organisms whose evolution favored fractal structures because of the efficiency and resilience they offer. Le Corbusier’s modernism relies only on translation symmetries, repeating the same oversized objects in a highly simplified space with only one scale. Le Corbusier removes from the *Radiant City* all the smaller and intermediary scales of the historical city to replace them by a giant scale duplicated by translational symmetry. Quite the opposite, from their multicellular growth over long periods of time historical cities have developed a scaling symmetry. In scale-free systems, inverse power laws relate scales: the frequency of an element of size x is proportional to the inverse of its size at an exponent m characteristic of the scaling properties of the system. There are few big elements, a medium number of medium-scale elements and a very large number (a “long tail”) of small-scale elements. The relative frequency of each type is determined by the scaling parameter of the inverse power law.

Why is scaling hierarchy a key factor of urban sustainability and resilience?

Historical cities, like Paris with its 2000 years long history, were slowly transformed by incremental phenomena of destruction and reconstruction of the urban fabric. Structures that were not resilient enough were eliminated. And so historical cities have come down to us with extraordinary capacities of efficiency and resilience. In a process of spontaneous self-organization to adapt their forms to fluctuations in their environment, historical cities acquired the capacity to absorb fluctuations by reinforcing their structure and order, and becoming more complex. Resilience may be defined as the ability of a system to evolve while keeping embedded in its structure the memory of its previous states. Transformation increases the number of scales without destroying the previous existing scales. It reinforces the scaling structure by enlarging it toward higher scales (Haussmann in Paris), by diversifying an original highly symmetrical state into a scaling structure (New York evolution under market forces), by intensifying it towards smaller scales (Tokyo or Kyoto plot fragmentation). Resilience is not an urban quality that can be reached by a strategy at only one scale. It is rather a property that emerges from the relationships between scales.

Urban evolution in Paris has created a multi-fractal fine grain platting structure embedding the memory of 2000 years of history

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Paris is not a city planned from the beginning. It is complex, connected, and highly differentiated while being integrated. Its urban form results from a balance between political and social power struggles, and market forces. The land division into parcels has maintained the historical continuity of the most ancient parts of the city (and now the most modern, vibrant and bustling of economic activity). The medieval land subdivision is the result of the city multicellular growth from successive subdivisions of noble and ecclesiastical censives. The successive morphogenetic ruptures of the medieval fortified walls created asymmetries still strongly visible in the platting five to six centuries later in the Napoleonic cadastre Vasserot of 1810-1836. The geometric characteristics of past and present plot layers allow analyzing the urban morphogenesis: surface, elongation index (ratio length/width), index of rectangularity (the surface of the plot considered in relation to the minimum bounding rectangular box and the convex envelope associated with it). Highlighting below 300 m² plots on the Napoleonic period Vasserot plan (1810-1836) confirms the high plot density on the more urbanized right bank compared to the more rural left bank. Per hectare there was on average 11 plots on the right bank against 8 on the left bank.

Figure 1: Left: Extracting on the 1810-1836 cadastral plan only the smaller plots (below 300 m^2 reveals a fractal pattern oriented according to the 2 morphogenetic axes of Antiquity and the Middle Ages. Right: Orientations plots segments in Vasserot map (1810-1836) [1]

The plot analysis reveals 2 major morphogenetic axes intersecting at right angle. The major orientation is between 60 and 74 ° with respect to east. It alone represents 36 % of the total of segments. It relies on two morphogenetic axes (that can generate and transmit forms): the alignment formed by rue Saint -Martin and Saint- Jacques, and the Seine. Archaeologists have identified this orientation as dominant in the Roman period. The morphogenetic axis of ancient Lutèce was based on a regular orthogonal grid aligned on rue Saint- Martin – rue Saint- Jacques, which is partly the cardo of the ancient foundation and builds on former islands formerly present in the course of the Seine. This orientation also dominates the network of streets that existed at the end of the fourteenth century. The Middle Ages have played a key role in the resilience of Roman period main orientation and its dissemination on the right bank. This Roman and Medieval axis still structures the most innovative economy in Paris.

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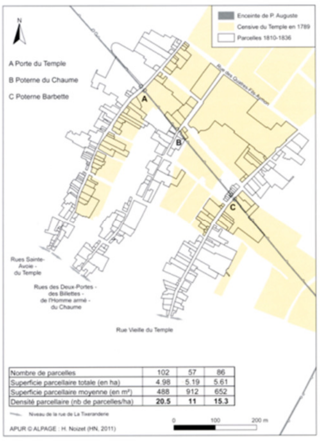

Figure 2: Platting (1810-1836) along 3 roads opened in the 13th century. Local scale breaks of symmetry have been transmitted throughout 6 centuries [1]

Minute breaks of symmetry in the urban fabric have been transmitted through centuries by long-term correlations. Platting geometry (size, orientation) is a time travel machine in layered urban strata. It embeds the memory of the city at extreme micro scales. Rue du Temple crossed Philippe Auguste wall through Porte du Temple, one of the original gates. Rue Vieille-du-Temple was opened very early, before 1203. Rue du Chaume was opened only in 1288. The analysis of plots in Vasserot plan (1810-1836) reveals a morphological hierarchy with 20.3 plots per ha for rue du Temple, 15.5 plots/ha for rue Vieille-du-Temple, 11.3 plots/ ha for rue du Chaume. The piercing of wall gates has been so structuring on the micro scale of the urban structure that 6 centuries after, at the beginning of 19th century, the spatial hierarchy of 13th century is still visible. From this long history with long-range temporal correlations emerged a multi-fractal urban structure, with local singularities and breaks of symmetry reflecting the stratification of different morphological periods. Scaling hierarchy of plot sizes is the "signature" of complexity.

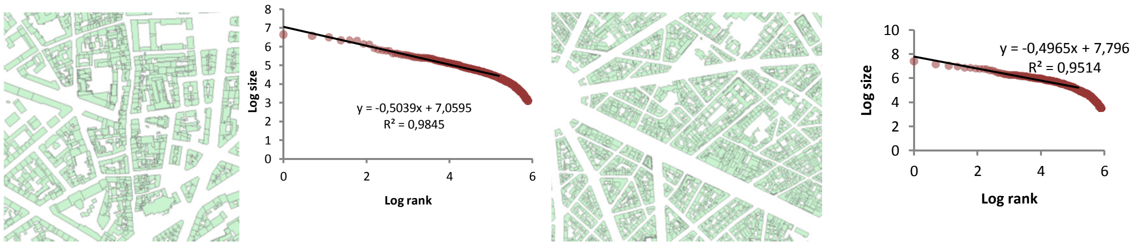

Figure 3: Right: Scaling hierarchy of plots' area along a structuring axis of Medieval Paris: rue Mouffetard. The largest plot is 760 m². Left: Quartier de l'Etoile. Plot scaling hierarchy in an Haussmannian neighborhood developed 7 centuries after rue Mouffetard. The largest plot is 1600 m^{2}. With much larger plots the scaling parameter remains almost identical. The city dilatation conserves the scaling hierarchy.

The emergence of a scale free platting in Manhattan under market forces

When discovered by Hudson in 1609, *Mannahatta* (« The Island with many hills ») had more ecological communities per acre than Yellowstone, more native plant species than Yosemite, and more birds than the Great Smoky Mountains National Park. Extreme ecological diversity has been replaced today by extreme human diversity. Towards the end of the American Revolution in 1776, the fundamentals of Manhattan, were almost unchanged since 2 centuries ago, except a town of 32, 000 inhabitants at the bottom of the island. After the American Revolution, the new and cash-strapped American city government looked to profit from its underperforming domain (about 2 square miles of rocky, hilly undesirable land in the middle of the island.

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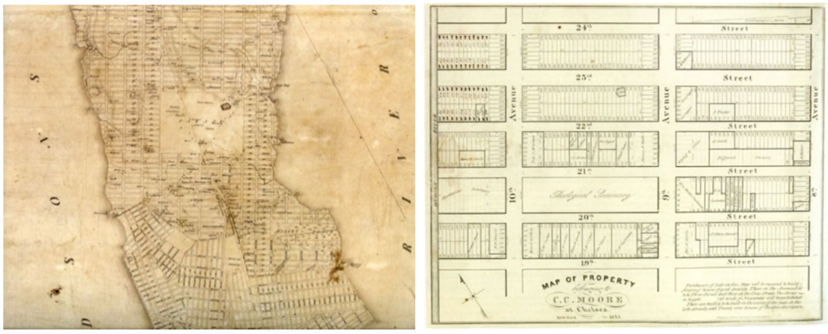

Figure 4: Right: Detail of Manhattan Commissioner's map of 1811. Left : Map of Charles Moore real Estate in 1835, which eventually became Chelsea

In 1811, the Commissioners' map of 1807 overlaid a seemingly uniform grid of rectangles over the rugged island. The grid was above all an easy format for the subdivision and development of land. The grid system stripped the land of topographical markers and specificity, and repackaged it as standardized building lots. The grid re-conceptualized the island in a real estate market. And it worked beyond all expectations. In 1807, the assessed value of New York City real estate was \$ 25 million. In 1887 it was \$2 billion, a 80-fold increase. From this seemingly homogeneous grid, how did highly differentiated neighborhoods emerge, with urban and social fabrics as different as Soho, Tribeca or the Upper East Side? In reality the grid contains 2 patterns that create variety. One pattern is formed by the street widths (30 meters for the avenues, 20 meters for standard cross streets, with 15 major cross streets 30 meters wide at irregular intervals. The second pattern derives from block dimensions. All blocks are 60 meters wide north to south, but their length east to west varies diminishing from the center to the shorelines. From Third to Sixth Avenue blocks are 280 meters long. Moving eastward they shrink 189, 198, 195 meters long. Moving westward, they shrink uniformly to 244 meters long.

Manhattan avenues are at a higher level in the hierarchy than Manhattan streets: first by their metric properties; second by their topological properties. Avenues are about 12,5 km long and 30 meters wide while streets are around 2.7 km long and 20 meters wide, except 15 major cross streets that are 30 meters wide. This break of symmetry in the pattern creates a metric scaling. But even more important is the break of symmetry in the topological properties of avenues and streets. Graph theory defines street continuity by the number of links between nodes (segments of streets between intersections). It defines a street connectivity by the number of other streets it connects (that-is it intersects). As Manhattan avenues connect 155 streets and are made of about 144 blocks, while Manhattan streets connect about 11 avenues and are made of 10 blocks, there is a steep topological scaling between avenues and streets. The scaling hierarchy in Manhattan street pattern comprised originally only 2 main scales (or 3 if we create an intermediary category for the main cross streets). This has been enough for the network to evolve in 200 years. The initial hierarchy with 2 levels has been transformed into a hierarchy with 4 levels, with towards the lower level small streets cutting through some blocks, and towards the upper level urban highways circling the island. This increase in hierarchy is reflected in the topological modifications of the grid. On a surface of 35.4 km^2,

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the number of nodes of degree 4 characteristic of the pure grid has remained stable (1592 now compared to 1460 in the Commissioner's plan) while the number of odd nodes (degrees 1, 3, 5 characteristic of singularities and of more complexity) has doubled from 369 to 670. The density of nodes has increased (+ 17% to reach 60 intersections/km^2) and the density of links has also increased (+21% to reach 11/km^2) but they remain much lower than in a complex network like Paris. Sustainable networks must achieve a right balance between complexity (which reduces connectivity) and connectivity (which reduces complexity) [2], [3]. The highly connective Manhattan grid has above all grown in connectivity compared to the Commissioners' plan by addition of new avenues (Lexington and Madison, which have divided in 2 the longest 280 meters blocks) and of Broadway diagonal.

Blocks were subdivided for land sale into identical plots of 205m^2 area, which, under the influence of market forces, started to consolidate and create a differentiated platting ordered by combinations of the same basic module very early in the process. Free market is a formidable time accelerator for differentiation and emergence of scale free structures. An example is the strategy of Charles Moore for developing his estate, which eventually became the vibrant and differentiated Chelsea neighborhood. Charles Moore developed his estate into Chelsea village, centered around Chelsea Square he had donated to the episcopal church in 1819. The break of symmetry created by the Square, Church and public garden created a cascade of differentiation in the size and value of the plots in relation to their location near or far from Chelsea Church. In 1820 Moore had evaluated his estate at $ 17,000. His wealth was estimated at $ 350,000 in 1845 and $ 600,000 in 1855, that is a multiplication by 35 in 35 years. Differentiation and asymmetry in land prices occurred very quickly in the seemingly uniform Manhattan grid. In 1860, real estate along Fourth Avenue ranged from $ 3,500 to $ 8,000, while lots along Madison Avenue were valued between $ 18,000 and 55,000 at proximity of Madison Square. These breaks of symmetry in plot size and land value created an enormous potential of differentiation. In a scale-free morphological field like the grid and platting system of Manhattan, the position and the form of each element are influenced by its interaction on different scales with all other elements. When the result of all these interactions creates a form, it is neither symmetrical nor fixed. It displays a degree of plasticity that allows it to evolve.

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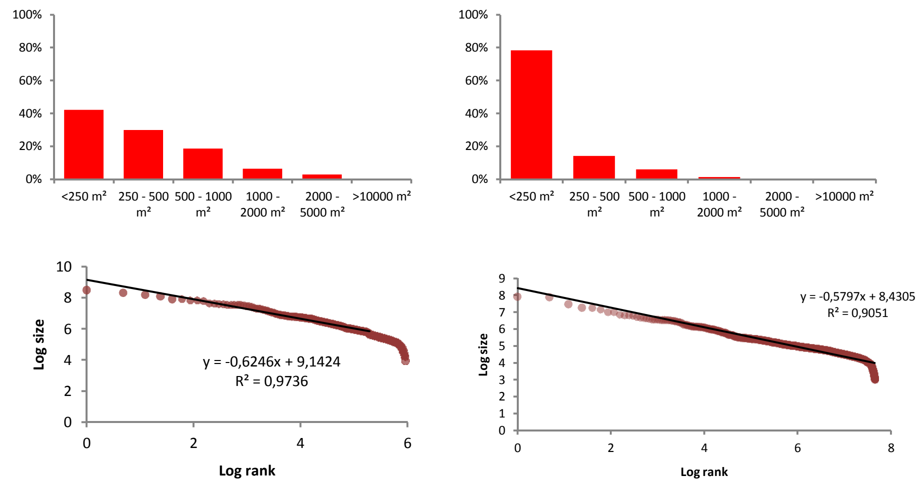

Figure 5: From an identical small-scale modular unit, the platting in Manhattan is highly adaptive: left around Madison Square, right in more residential Brooklyn, with corresponding rank size analyses.

Highly adaptive Manhattan platting follows an inverse power law with a scaling parameter higher than in Paris (0.6 compared to 0.5), showing a steeper hierarchy of scale. It is interesting to note that the scaling parameter in Lower Manhattan, which has the much longer history of being formerly the Dutch town of New Amsterdam, of which it has kept almost unchanged its street pattern, has a scaling parameter of 0.5 characteristic of an European city like Paris. 40% of the plots around Madison Square have kept the original platting of early 19th century, while the other 60% have consolidated at various sizes. In more residential Brooklyn, 80% of the plot sizes date back to early 19th century. The plot sizes distribution inverse power laws allow for a large variety in the diversification of neighborhoods. Fast emergence of complexity of urban fabric, real estate market and economic activity in Manhattan led to a multiplication by 8 of the population in 50 years making Manhattan as early as 1860 one of the largest city in the world with 800 000 inhabitants and to a multiplication by 80 of the real estate value of the city in 80 years (between 1807 and 1887). Emergence of complexity was fostered by breaks of symmetry in the apparently homogeneous grid and by a fine grain market of about 300,000 land plots of 205 m^2 (quite interestingly the size of plots of South West of France medieval 12th century new towns called "bastides"). As a comparison on the same area of 66 km^2, Chinese new urban developments display only about 250 giant superblocks (1200 times less due also to the oversized infrastructures compared to the Avenues and Streets of Manhattan). This lack of fine grain restricts the market to 3 to 4 giant developers and prevents the emergence of a free market for land with a diversity of actors. This lack of market mechanisms is responsible for the economic failure of these new Chinese developments and their transformation into ghost towns with 64.6 million empty homes while 260 million urban migrants are waiting for decent housing. In New York on the contrary, 2 centuries of complex uneven growth and intensification have led to an extremely bumpy multi-fractal urban landscape for demography, development, energy, and most urban parameters.

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What should planners do and must not do?

Emergence is the opposite of the utopian simplified orders that architects such as Le Corbusier have tried to impose on cities. Huge quantities of energy are needed in such artificial repetitive orders to maintain urban systems in a stable state. Modernist cities, with abstract giant forms imposed from the outside, obstruct the emergence of small-scale connections, whereas the continuous creation of connections in historical cities favored their evolution. Giant modernist buildings standing in loneliness isolation do not connect into the urban fabric. They have a destabilizing impact and fail to create an evolving adaptive structure. Modernist architects turned their back to the universal laws of urban evolution by working with large-scale elements only and making the urban land a blank slate devoid of the incremental successive layers of historical traces. The Utopian machinist juxtaposition of vast homogeneous zones, made of a repetition of very big objects, hinders the appearance of emerging properties that were not integrated or even forecasted or predictable into the initial framework of the system. Planners should create the framework for future evolution. They should not constrain this evolution. Successful plans are simple but subtle plans that leave ample room for unexpected and unpredictable change while enduring for millennia. Roman empire plans lead to cities as different as Torino, Firenze, Bologna, and Paris. When the Commissioner's designed Manhattan map in 1811, long before the Industrial Revolution, in the period of Napoleonic wars in Europe, none of the technologies that made the power and wealth of the city in the 20th century could have been imagined: electricity, automobiles, subways and elevators where not only unpredictable, they were unthinkable, they were undreamt nightmares of a distant future. Without them, the typical urban form of Manhattan, the skyscraper, could not have been built. And yet, the Commissioner's plan was able to accommodate the unpredictable and to endure for 2 centuries, making Manhattan the world economic capital. Urban form does not follow function. It must successively or simultaneously adapt to many different and even contradictory functions. Planners should understand that the future cannot be controlled and that attempts to control it leads to dead cities, to ghost towns. Living cities are like chessboards where an endless number of different games can be played. It is the role and responsibility of the planner to design the chessboard not to play the game. Life should play the game.

References

[1] H. Noizet, B. Bove, and L. Costa, *Paris, de parcelles en pixels : Analyse géomatique de l'espace parisien médiéval et moderne*. Saint Denis: Coédition PU Vincennes, 2013.

[2] S. Salat, *Cities and Forms*. Hermann, 2011.

[3] S. Marshall, *Streets & patterns*. London; New York: Spon, 2005.

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Session 32:

Is zero carbon design an adequate solution for sustainable development?

Chairperson:

Higueras, Esther

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Study on Residential Policy of ZEH for Local Action in Taiwan

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Abstract: *In Taiwan, a large number of energy source relies on imports. According to the data, the import rate of the energy already raises up to 99.4% during the past decades. Because of the density of the population and geographical condition, large-scale renewable energy development is not preferable in Taiwan. Therefore, developing small-scale renewable energy for implementing the zero energy houses is a critical task.*

Moreover, IEA key world energy statistic shows that the average CO_2 emission per person is 11.31 ton-CO_2/capita in Taiwan. Compared with OECD countries, such as Japan, Finland, Norway, and Denmark, the average CO_2 emission per person of Taiwan remains high. According to the reference, the CO_2 emission of construction industry is accounted for almost 30% of the total CO_2 emission in Taiwan. Not belonged to OECD, Taiwan still hold the responsibility with CO_2 reduction. Thus, how to eliminate the carbon emission and to develop ZEB (Zero-Energy Building) are crucial issues in Taiwan.

Kaohsiung is the second largest city in Taiwan; the local government is working positively to make Kaohsiung a sustainable city. Thus, the local government promoted the "Kaohsiung House Project" in 2012, which is to demonstrate a sustainable building model for residential buildings. The objectives of the project are to minimize environmental load, inspire the local culture and improve healthy environment.

In this study, a ZEH (Zero Energy Home) model was proposed for reducing environmental load in Kaohsiung. A detached house was selected as the study case. Based on the weather data of Kaohsiung, the southern city in Taiwan, the potential of renewable energy was analysed. Also, residential energy consumption was accessed, and then the energy conservation design of zero energy home. Finally, economic analysis of the new ZEH design was carried out to suggest financial aid policies for government.

Keywords: zero-energy home (ZEH), annual energy consumption, design strategies, EnergyPlus

Introduction

Zero-energy buildings (ZEBs) are a realistic solution to the challenge of creating energy-efficient buildings (Marszal et al., 2011). ZEBs are efficient buildings that can draw from outside sources an amount of energy that is equal to or less than the energy produced on site by using renewable energy sources (Deng et al., 2011). Plans for constructing ZEBs have been proposed in Europe and the United States. The European Energy Performance of Buildings Directive (EPBD) established "near-ZEB" standards, specifying that all public buildings in the European Union (EU) must be near-ZEBs by 2018, and that by 2020, all new residential, commercial, and school buildings should be constructed according to the regulations (EPBD, 2010). The U.S. Energy Information Administration specified a target of net-zero energy consumption for all commercial buildings in the United States by 2050.

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Because of the increasing energy demand and rapidly changing climate, ZEBs have become an international development trend (Crawly et al., 2009).

In Taiwan, the supplementary energy structure relies mainly on thermal and nuclear energy. However, 99.4% of these energy resources are imported. Development of renewable energy sources is slow even though the Taiwanese government recognizes its importance. The Ministry of Economic Affairs declared in 2011 that 8% of the total power generated in Taiwan should be produced using renewable energy sources before 2050. However, renewable-energy production in 2013 was lower than 0.5% of the total energy production.

Furthermore, according to the IEA Key World Energy Statistics, the average CO_2 emission per person in Taiwan is 11.31 ton, which is high compared with that in OECD countries such as Japan, Finland, Norway, and Denmark. Moreover, the construction industry accounts for approximately 30% of the total CO_2 emission in Taiwan. Because of Taiwan's high population density, large-scale production of renewable energy is not feasible. Therefore, eliminating carbon emission and developing ZEBs are crucial objectives.

Kaohsiung is the second largest city in Southern Taiwan and has a hot and humid subtropical climate (N'22 E'120). Recently, the Kaohsiung government proposed a project for promoting the Kaohsiung House, which follows four standards: environmental loading, sociocultural and perceptual aspects, service quality, and indoor environmental quality. The purpose of the project is to create an ecocity. According to these standards, the Kaohsiung House proposals are separated into urban and rural houses according to the local geographical and climatic conditions. The policies for the Kaohsiung House Project will be based on these proposals.

This paper proposes an energy-efficient design strategy for residential buildings in consideration of the feasibility of renewable energy use according to local climate data. In addition, models for ideal zero-energy farmhouses are suggested. A detached house in rural Kaohsiung in Southern Taiwan was used as a study case. An economic analysis was conducted and potential financial-aid policies are suggested.

Methods

Case Study Subject
A detached house in rural Kaohsiung was used as the study case for proposing suitable architectural design strategies for ZEH. The county of Kaohsiung has a population of approximately 2,779,000 and an area of approximately 2,947 km^2. The plain is the main topography, and the primary residential building type in suburban areas is the detached house.

Original Design
The total area of the jobsite is 916 m^2. The original draft for the design of this house, shown in Figure 1, represents a typical layout for houses built in suburban Kaohsiung. The total floor area of this plan is 276 m^2, providing sufficient space for six people (three generations) in five bedrooms, three bathrooms, two balconies, one living room, and one dining room. The proposed ZEH is based on the original residential programs.

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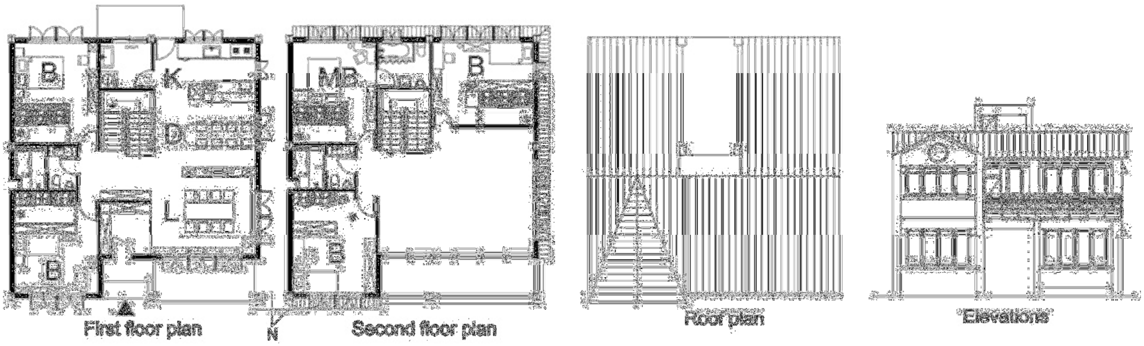

Figure 1. Original design draft of the study case

Proposed Design for Energy Conservation

Various factors must be considered during the housing design process. In this study, strategies for saving energy by reducing air-conditioning energy consumption were developed, and the forms of structures and roofs, depths of sun visors, locations of windows, and types of balcony were simulated using EnergyPlus. The results of these simulations were used to propose fundamental design strategies for ZEH. Moreover, to estimate the future power consumption of the proposed residence, EnergyPlus was used in simulating residential energy consumption to facilitate comparison of the original design and the proposed design.

Simulation Model Setup

The simulation was based on Kaohsiung weather data. Air conditioning was used from 17 pm to 12 am from May to November, when the indoor temperature is over 28 °C. The model was constructed using reinforced concrete, and the building materials used were commonly available in Taiwan.

Evaluation of Renewable Energy Generation

The evaluation of the potential for using renewable energy in a residential building was based on data on the hourly weather in Kaohsiung. The number of hours of sunlight in Kaohsiung per year is approximately 2212 hr/yr, which is the second highest among the cities of Taiwan. To calculate the power generated by photovoltaic (PV) panels, direct and diffuse solar radiation were first separated according to statistics on horizontal solar radiation and then combined using PV panels tilted at various angles. This study used 235-W PV panels produced by S. Company; the module efficiency was 18.3%. According to the solar power generation algorithm published by the Institute for Building Environment and Energy Conservation of Japan (2010), the generation capacity of PV panels can be calculated as follows:

$$Ep = P \div \alpha \times H \times K \times 365 \qquad (1)$$

where Ep is the predicted annual power production (kWh/yr), P is the system capacity (kW), α is the standard solar radiation (kWh/m^2), K is the design coefficient, and H is the daily solar radiation [kWh/(m^2/day)].

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Results

Design Proposal of ZEH for Kaohsiung
A ZEH plan incorporating solar panel design strategies and residential design strategies was proposed based on the forms of structures and roofs, depths of sun visors, locations of windows, and types of balcony. The proposed house is shown in Figure 2.

The total floor area of the proposed design is 232.6 m^2, which is sufficient for two elderly people, two adults, and two children; these features are identical to those of the original design. LED lighting replaces the traditional lighting. The annual total power consumption of the proposed design, as calculated using EnergyPlus, is 4561.8 kWh, exhibiting a 60% reduction in lighting and a 11% reduction in air conditioning compared with the original design. The proposed design can reduce total energy consumption by 8% (Figure 3).

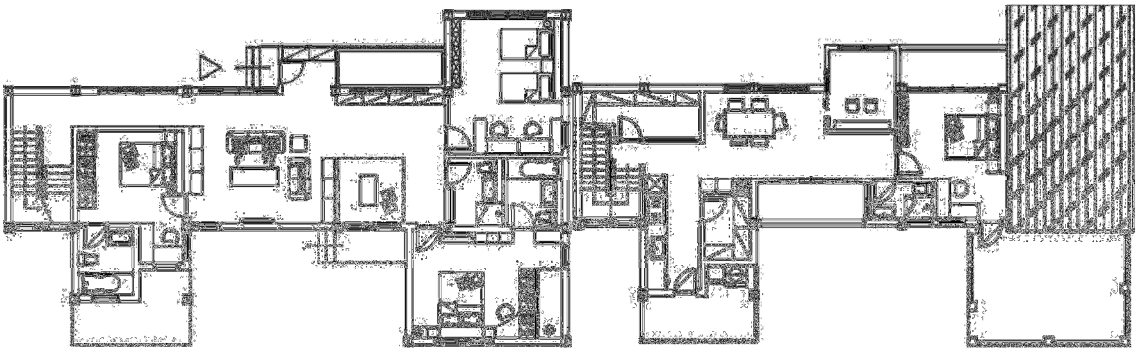

Figure 2. Proposed design draft of the study case

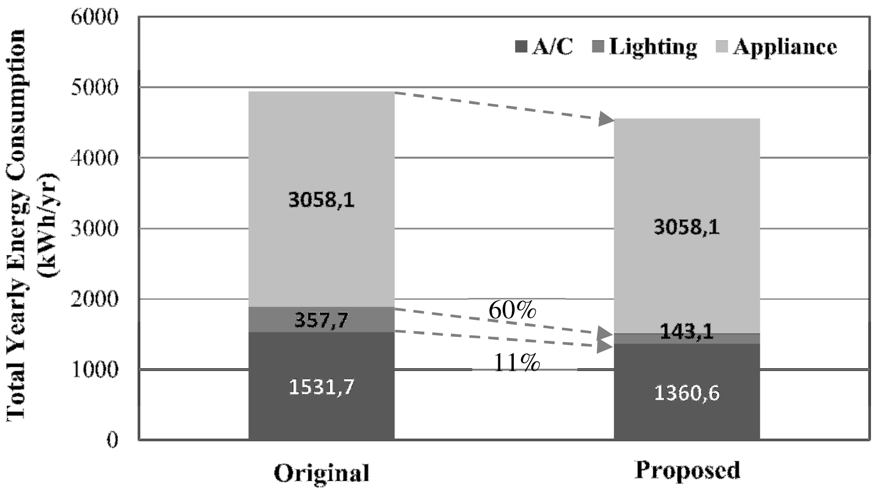

Figure 3. Total energy consumption of the original and proposed house

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Results of the Renewable Energy Generation Evaluation
Analytical data on solar radiation and the direct-diffuse segregation technique were used to determine that the optimal azimuth is south and the optimal tilt angle is 20°; under these conditions, each PV panel ccan produce 233.2 kWh/yr. The yearly energy consumption for the original house is 4947.5 kWh/yr, whereas that for the proposed ZEH is 4561.8 kWh/yr. According to the evaluation of renewable energy generation, 22 panels are required for the original house and 20 panels are required for the proposed ZEH.

Discussion
Regarding the Kaohsiung House Project conducted by the government, considering the economic aspect of the proposed policies is crucial. Renewable energy has not been popular even though it has been promoted by the government because of the high cost of the equipment and poor returns on investments. In this study, the cost of the PV panels and the payback time for various proposals were calculated.

The single PV panel used in this study costs 853 USD and the basic construction cost for a house is 183,333 USD, which is 775 USD/m^2. According to the published electricity prices in 2013, 1 kWh costs 0.18 USD in summers and 0.15 USD in other seasons. The buyback electricity price is 0.27 USD/kWh. Based on the aforementioned prices, the original house can save 707 USD and the proposed ZEH can save 514 USD annually. However, the payback time is 14 years for the original house and 13 years for the proposed house if the half life cycle of the building is 20 years.

Proposal I, in which the Kaohsiung city government provides financial aid at the initial stage, is 2600 USD for the original house and 1733 USD for the proposed ZEH. Thus, the payback time for Proposal I is 10 years. This paper suggests two proposals for promoting renewable energy in Kaohsiung. In Proposal II, 25% financial aid is provided for PV panel investment, and, in Proposal III, the buyback electricity price is increased to 0.33 USD. A comparison of the three proposals is listed in Table 1.

Table 1. Comparison of the investments by citizens and the government

	Proposals	PV Panels	Description	Investment		Payback Time (Year)
				Citizen (10^3USD)	Government (USD/15 years)	
Original	No PV	0	No Financial Aid	183	0	--
	PV installed	22		207	0	13.5
	Proposal I		433 USD/kWp*	204	2,851	11.8
	Proposal II		25% initial cost**	201	5,973	10.1
	Proposal III		0.33 USD/kWh***	207	5,941 (396/yr)	10.9
Proposed ZEH	No PV	0	No Financial Aid	183	0	--
	PV installed	20		200	0	13.5
	Proposal I		433 USD/kWp*	198	2,037	11.8
	Proposal II		25% initial cost **	196	4,267	10.1
	Proposal III		0.33 USD/kWh***	200	4,244 (283/yr)	10.9

* The 2013 solar renewable energy financial aid for buildings in Kaohsiung city (433 USD/kWp).
** 25% of total solar panel investment (908 USD/kWp).
*** The buyback electricity price increased to 0.33 USD/kWh without investment aid.

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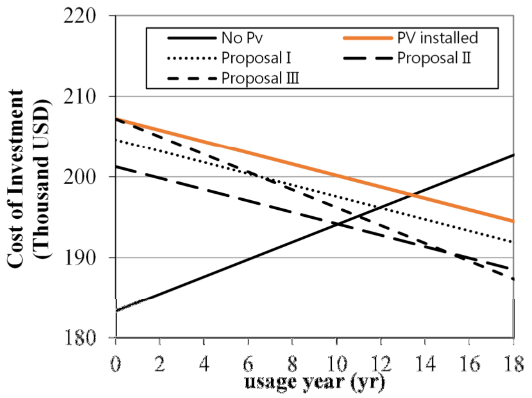

Figure 4. Investment and payback for the original house

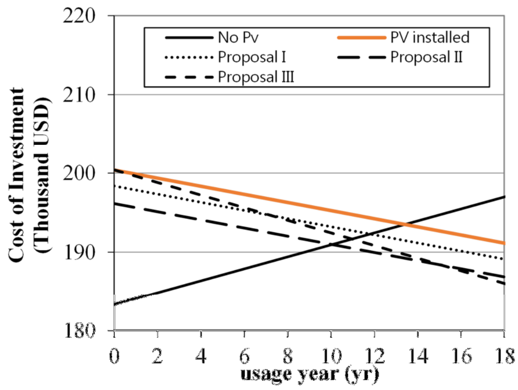

Figure 5. Investment and payback for the proposed ZEH

According to the results, the payback time for the original house can be reduced to 11.8 years, 10.1 years, and 10.9 years by implementing Proposals I, II, and III, respectively; for the proposed ZEH, the payback time is the same.

The investments made by citizens and the government over a 15-year period are listed in Table 2. Regarding the proposed ZEH, although investment by the government in Proposal II and III is approximately 2-fold greater than that of investment in Proposal I, the payback time can be reduced by 2–3 years and the participation of citizens can be increased. The government invests in Proposal II at the initial stage, whereas Proposal III is paid for in installments.

Conclusion

In conclusion, this study determined financial solutions for building a ZEH in Kaohsiung, Taiwan. Solar power was analyzed and considered crucial for generating residential power. Moreover, a ZEH was proposed based on the developed strategies and optimal solar power generation conditions (20 PV panels tilted at 20° angles). An economic analysis indicated that the payback time is 10.1 years when 25% of the PV panel investment is subsidized and 10.9 years when the energy buyback price is increased to 0.33 USD. These financial aid policies can reduce the payback period. The authors hope that the results will be applied to ZEHs in the future to improve the comfort and health of the occupants, and that the results will provide a reference for relevant industries in Taiwan.

Acknowledgement

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References

Bureau of Energy, Ministry of Economic Affairs, "Electric Sales Statistics/industry electricity consumption,"http://www.moeaboe.gov.tw/, 2001 (in Chinese).

Central Weather Bureau, "2003-2007 Hourly weather data," http://www.cwb.gov.tw/V7/index.htm, 2008.

ISBN: 978-84-697-1815-5

Crawley D., Pless S., and Torcellini P. "Getting to net zero,"ASHRAE Journal, Vol. 51, Issue 9, Sep. 2009.

Deng S., Dalibard A., Martin M., Dai Y.J., EickeU. r, and Wanga R.Z., "Energy supply concepts for zero energy residential buildings in humid and dry climate,"Energy Conversion and Management, vol. 52, no. 6, pp. 2455–2460, Jun. 2011.

EPBD, "The Directive 2010/31/EU," Official Journal of the European Union, Linear Networks and Systems, Belmont, CA: Wadsworth, 18 Jun. 2010, pp. 13-35.

Graça G. C. da, Augusto A., and Lerer M. M., "Solar powered net zero energy homes for southern Europe: Feasibility study,"Solar Energy, vol. 86, no. 1, Jan. 2012, pp. 634-646.

Institute for Building Environment and Energy Conservation, "Engineering in energy construction standards of judgment of Residential - Consumption calculation method explanation," 2010 (in Japanese).

International Energy Agency, Key World Energy Statistics 2013 Edition, IEA, 2013.

Marszal, A.J.,Bourrelle J.S., Musall E., Heiselberg P., Gustavsen A., and Voss K., "Net Zero Energy Buildings – Calculation Methodologies versus National Building Codes," in: EuroSun Conference,Austria: Graz, 2010.

Marszal A.J., Heiselberg P., Bourrelle J.S., Musall E., Voss K., Sartori I., and Napolitano A., "Zero Energy Building – A review of definitions and calculation methodologies Original Research Article", Energy and Buildings, Vol. 43, Issue 4, pp. 971-979, Apr. 2011.

Ministry of Economic Affairs, "Sustainable Energy Development Programme,"http://www.moeaboe.gov.tw/, 2011 (in Chinese).

Nagata T., and Sawada K., "Proposal of the expression the sky diffusion radiation on a horizontal surface," Summaries of Technical Papers of Annual Meeting Architectural Institute of Japan, 1978 (in Japanese).

Shunroku T., Takeda H., Male T. T., Iwata T. and Teraoroad H., "Textbook of Architectural Environmental Engineering," 3rd ed, Inoue Shoin, Japan: Tokyo, 2006.

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Paths towards zero carbon city using nanotechnology Tripoli city case study

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Abstract: The next generation of sustainable design ought to help us reduce the impacts on the environment in a challenge to live more ecologically on day-to-day basis. Architects and designers from all around the world are joining a movement to create buildings that mitigate global warming and climate change. Zero-energy and carbon neutral architecture has emerged as a top priority, although low-energy and low-carbon design is often more readily achieved [4]. The study examines Tripoli as a city-case study that suffers from high levels of toxic gas emissions mainly CO2. It aims to put the basic strategy toward Tripoli zero-carbon city on basis of zero carbon buildings that uses nanomaterials technology as a solution.

Keywords : Global warming, Decarbonization, Nanomaterial, Nanotechnology.

1. Introduction: **Global warming has already taken place as the biggest problem of our time. The challenge is to find ways for the world to switch from a path of increasing gas emissions to a path of eliminating the gas emissions (mainly greenhouse gases) by adopting more high advanced technologies. Decarbonisation allows cities to develop as centres of healthy, multifaceted lifestyles with minimal environmental footprints. Tripoli is considered the second capital of Lebanon, after Beirut. The Tripoli Decarbonisation strategy could offer a foundation for custom designed plans for other suffering cities in the developing countries. To move forward, it requires more than new energy efficient buildings or new hybrid cars. The urban ecosystem should rely on the true integration of the city's elements (Buildings, waste system, water systems, energy networks, transporta-tion and infrastructure). Smart buildings rely on smart transit networks; smart energy systems rely on the creation of smart infrastructure [1].**
Energy is used during constructing and operating buildings, but it mainly records high levels during the operation phase. This lays responsibilities on designers and building's inhabitants to adopt sufficient solutions to decrease energy consumption. The strategies adopted to reduce CO2 emissions during operation include: reducing energy consumption, switching to renewable energy and implementing new technology sources in design such as green nanotechnology. Aside of being a solution to decrease buildings' incorporation in different emissions of gases, nanotechnology helps to overcome environmental issues by developing built materials that do not pollute. One has to predict that new technology will be required to use in 21st century, thus it ought to be well understood to use in a right way in order to reach Zero Carbon cities.

Tripoli, like many other local cities, had scored in recent years a high percentage of CO2 emission. The traffic congestion is considered a main reason of pollution. But, buildings remain the major contributor in increasing CO2 levels in the atmosphere. To face the lateral problem, the study aims to adopt a Decarbonisation plan that concentrates on using new green nanotechnology in buildings. Relatively, two main questions are raised: -**What are the paths and strategies towards Decarbonisation Tripoli city? Moreover, how can we achieve a net Zero-carbon building through green nanomaterials?**

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The object of this study is to put a comprehensive vision of how Tripoli can become more sustainable by adapting existing buildings with nanomaterials as solutions.

2. Current situation of Tripoli environmental pollution: **Based on the World Bank study, the loss of human life in Lebanon because of both premature mortality and disability could be as high as 1.0 million disability adjusted life years (DALYs). Environment-related causes may be responsible for about 15 % of this total, with 87,000 DALYs lost each year due to poor water quality, lack of access to water, and sanitation and hygiene, and another 65,000 DALY's lost to air pollution and over-crowded housing [3].**

A survey of emission contribution of each type of pollutants started in the three cities of the AL Fayhaa Community: Tripoli, Mina and Beddawi. The field questionnaires were prepared to lead to a reli-able data, where the collected data was then entered to GIS program. The calculation was implemented for the main pollutant emissions from the mentioned sectors. Seven main sources of air pollution were considered in the inventory: 1) Large, medium, small industries & small workshops, 2) Domestic heating & electrical generators, 3) Road traffic, 4) Shipping activities, 5) Fugitive emissions from road traffic, 6) Petroleum activities and 7) Others. According to urban community Al-Fayhaa, Tripoli city and its surrounding scored in 2001 (710967, 76 Ton/Year) of CO2 emission. The traffic congestion with stressful commutes in machines which powered by fossil fuels deliver untold metric tons of carbon into the atmosphere.

3. Application (Minkara Villa): **A typical residential building in the South periphery of Tripoli city is chosen as case study building. The analysis of the building background, energy demand, used material, and energy efficiency is essential to specify the nanomaterial and nanotechnology needed to upgrade the building performance and to reduce carbon emissions. The project is located in Qalamoun at the South of the Tripoli, having a maritime temperate climate at 34^{o} 23' 44.44'' North Latitude and 35^{o} 48' 4.77'' West Longitude (Figure 1).**

Figure 1. **Minkara Villa Perspective design**

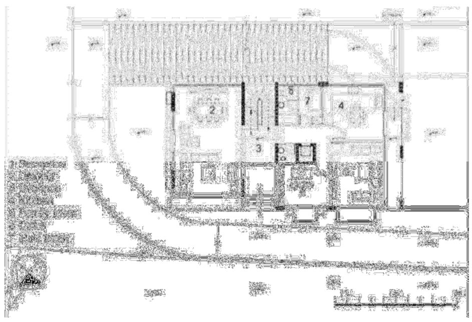

Figure 2. **Ground Floor Design**

The importance of this project is signified by its location and the usage of solar panel system as an electricity source. These two issues are considered the first step toward zero carbon architecture. The project site -Qalamoun- is considered a Tripoli suburban. Hence, it is noticed that CO2 emissions caused by vehicles are somehow very low. However, the project confronts the sea, possessing a high humidity level at this location. This constraint should have been considered in the first design. The project is around 540 m2, a total of three floors.

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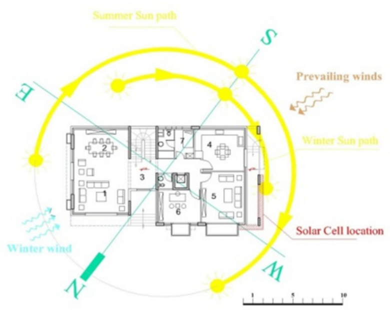

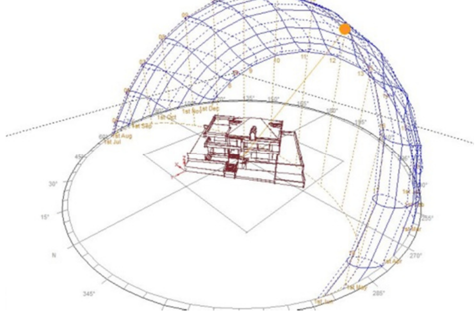

Figure 3, 4. Orientation of the project

The ground floor contains the reception area, kitchen and family room, with an extension to the outdoor garden. Almost each floor is about 180 m2 area (Figure 2). The project has a North South orientation with a grave deviation aligned with the land limit, 36º from a north-south axis. The North entry orientation is suitable. The South East elevation has a high thermal insulation with a small glass opening and 35 cm double insulated layered wall that decreases the heat transfer in the hot season. However, some architectural features found in the house are set in contrast with the sustainable principles ought to be followed during the design. The kitchen's position in front of prevailing wind is not quiet appropriate. It enhances the transportation of odors into the house (Figure 3, 4). In addition, natural ventilation strategies are not adopted in the project. Another conflict noticed during the analysis is locating PV panels in the west and north elevation, where it could be much effective if it is situated at the south elevation or inclined roof.

3.1. Curent case study building materials (as-built material): The structure used in this project is based on reinforced concrete structure with masonry block walls as internal wall partitions. The external walls consist of double masonry block walls with EPS insulation. The cladding is white cut stone (Figure 5) with composite aluminum cladding fixed at the north and west elevations. The building's envelope is composed of more than 80% stone, which reduces the opening glass area, most certainly in the South East Elevation.

Figure 5. *External wall with cut stone.*

a) Cavity wall with EPS insulation: The external wall in the case study project consists of a double cavity wall with 5 cm Expanded Polystyrene insulation (EPS) (Figure 6). EPS has a low to medium (Table 1). EPS, known also as the white polystyrene, has more than the half of the market-share; with an average of 61.3% of the thermal insulation market in Lebanon [5].

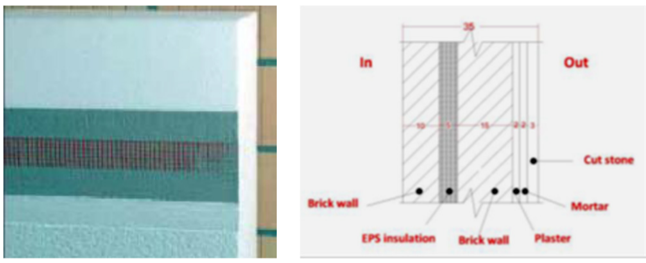

Table 1. Benefits and disadvantages of EPS insulation

Advantages	Disadvantages
• Excellent mechanical properties	• Degradation characteristics in case of long exposure to UV radiations
• High thermal performance	• Energy required to produce the material is big
• Low cost of this material	• Non-recyclable
• Rot proof (not biodegradable)	• Non-renewable resource
• The ease of implementation	• Poor long-term dimensional stability
	• Sensitive to water

Figure 6. *Double wall section with EPS insulation.*

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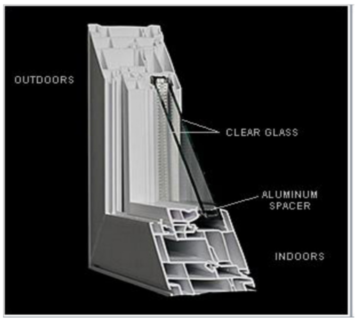
b) Double Clear Glazing: It was used in the external windows and doors, and offers some thermal insulation. It is made of two clear glass panes separated by an air gap that acts as insulating barrier between the window panes, and it is considered an effective way to reduce the conductive heat transfer. Compared to single glazing, it can cut heat loss in half. The double-glazed unit with clear glass also allows the transmission of high visible light and high solar heat gain (U value= 0.47). It transmit 70% of solar heat (SHGC=0.70) and 79% of visible light transmitted (VT= 0.79) (Figure 7).



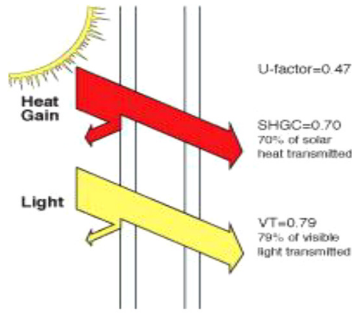


Figure 7. *Double clear glazing system with thermal absorption.* ***Figure 8.*** *Solarline heat pump system*

3.2. As-built solar system: The current system used in the building is the heat pump system from Solarline manufacture. The aim behind using this system is to provide heated water in winter time for the heating central system, where also the used water is reused in the cooling system in summer time. To reduce the use of non-renewable energy, Solar-line directly uses the "solar electricity" produced by the solar panels.The system is composed of 32 solar collector panels, battery, compressor and three water tank to storage the hot water (Figure 8). The solar collector is "Q-cells Q.Smart UF 85" from Q-cells Company(Table 2). The panel is sized 119 x 63 x 0.73 cm (Figure 9), 0.75 m 2 area. The 32 PV panels are set on a 24 m2 area, at the west and north façade of the villa (Figure 10). We need to calculate the necessary number of photovoltaic panels needed and the amount of electricity that should be generated by the panels. The first step in designing a solar PV system is to find out the total power and energy consumption of all loads needed by a Typical house. The máximum energy usage in the house is scored in August month due to the excessive need of cooling in this period. Therefore, the electricity bill, used as reference, belongs to July and August months .

Table 2. Q.Smart UF 85 electrical characteristics

Nominal Power Tolerance (+5/-0 %)	P max	[W]	85.0
Short Circuit Current	Isc	[A]	1.68
Open circuit Voltage	Voc	[V]	73.1
Current at Maximum Power	Imp	[A]	1.49
Voltage at Maximum Power	Vmp	[V]	57.2
Maximum System Voltage	1000V(IEC) / 600V (CSA/UL).		

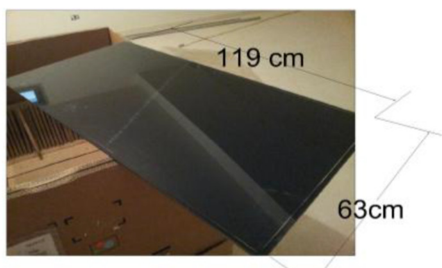


Figure 9. *Solar panel Dimension.* ***Figure 10.*** *South West and North West elevations*

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- Calculate total Watt-hours per day. Referring to the electricity bill, there is a consumption about 653 KW during 2 months. We can conclude that we have: 653000 Watt through 60 days, so we have approximately 10,883 w/day. Multiply the total appliances Watt-hours per day times 1.3 (the energy lost in the system) to get the total Watt-hours per day must be provided by the panels.

10, 883 watt x 1.3 = 14, 1479 watt

- We have to consider "panel generation factor" which differs at each site location. In Lebanon, the summer day is of a long day length and high brightness intensity, amounts to average 7 hours per day (http://www.upsaps.com). Calculate the total Watt-peak rating required for PV modules. Then, divide the total Watt/hours per day needed from the PV modules by 7 to get the total Watt-peak rating needed.

14, 1479 watt / 7 = 2,021.12 wp

- To calculate the number of PV panels for the system, we divide the answer obtained by the rated output Watt-peak of the PV modules. Increase any fractional part of result to the next highest full number to get the number of PV modules required.

2,021.12 / 85 = 23.7 modules

Referring to the previous calculation, the number of PV panels needed to cover the electricity bill is 24 panels. However, the electricity bill doesn't represent the total energy used of the project due to the finance state incapability and the high price of fossil fuel. Therefore, the referred electricity bill represents 50% of the actual consumed electricity. On the other hand, the solar system is still not financial feasible. In this project, the solar panel system cost $100,000 as initial cost. To calculate the duration payback, we compare the initial cost of the solar system with the tariff bill cost, which scored an average of 0,05$/kW. The system used aimed to generate 8kw/h. Therefore, it aim to generate 8kw/h x 24 x 360 = 69,120 kW per year. This quantity cost 69,120kw x 0,05= 3,456 $/ year. **The number of year to payback** the initial cost of the system is estimated about $100,000/$3,456= **27 years**. Today, at least 90% of photovoltaic sales are made from silicon-based solar cells. Some experts believe that the pace of solar development will be slowed due to the rising cost of its primary raw material, silicon. [2]

3.3. Proposed Nanotechnology solutions: On behalf of the above mentined information, we seek to convert the villa to an environmental friendly building using nanotechnology. Besides, we foresee to retrofit the existing orientation with the environment of the existing building, so that it would respond effectively to undergoing climatic change. To achieve these two goals, we suggest three main categories of nanotechnology:

3.3.1. Solar Energy:

a) Nanosolar Utility Panel : In addition to the used Q-cell PV system, the Nanosolar Utility panel is chosen as alternative solar panel to generate the 50% needed of electricity in the Minkara house. It is characterized with a thin panel of 160-220 Watts (Table 3).

Table 3. Nanosolar Utility Panel ™electrical characteristics

Nominal Power Tolerance (+5/-0 %)	P max	[W]	220
Short Circuit Current	Isc	[A]	6.4
Open circuit Voltage	Voc	[V]	53.2
Current at Maximum Power	Imp	[A]	5.5
Voltage at Maximum Power	Vmp	[V]	41.4

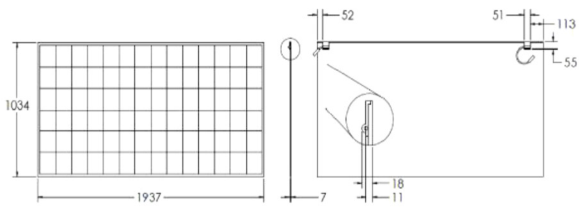

Figure 11. *Nanosolar Panel Electrical dimensions*

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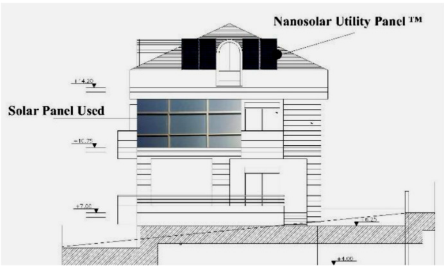
The dimension of Nanosolar panel is (1.9 x1.03= 2 m2). The number of needed panel on the roof (2,021.12 / 220 = 9.1 modules) is 10 panels (Figure 11). So, the total area needed on the roof is (10x2=20 m2) for installing the Nanosolar panels. The 10 Nansolar panels are to be placed at the Southern and Western elevation of the inclined roof with 25º inclination. Six panels can be situated at the Southern side and the other four to be placed at the Western side. (Figure 12-13).Comparing to the current PV system, Nanosolar has high power per panel that reduces the installation cost, a high current design that enables longer panel arrays, the ability to reduce cabling and labour, a high-system voltage industry-first 1500V certification. In a market friendly scenario, Nanosolar claims to be able to produce electricity at 5-6 cents/kilowatt hour almost as cheap as power from coal and at about one-third the cost of other solar power.



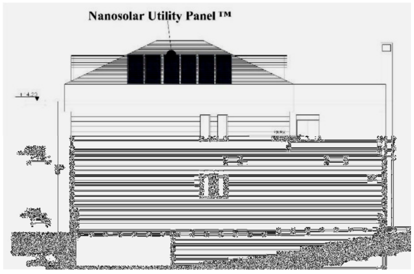


Figure 12. *South Elev.with integration of 6 panels* ***Figure 13***. *Westren Elev. with integration of 4 panels.*

b) Anti-reflective coating : The current disposition of the Q-Cells in the North elevation is not compatible with the sun path. Therefore, to maximize the module efficiency, the incident sunlight received should not reflected en route to the absorber layer. An antireflective coating is suggested to be added to the glass of the used Solar panel modules. It can improve the light transmittance of the glass by reducing the amount of reflection on the surface. Transparent nanoscalar surface structures offer not only an innovative but also a cost effective and efficient anti-reflective solution. A thickness of 150 nm is regarded as ideal. The degree of transmission at low angles of incidence can become much better than before, making such systems less dependent upon the angle of the sun. By reducing the amount of under utilise and therefore lost solar energy, the energy gain and efficiency of the photovoltaic systems is improved, resulting in overall performance gain of up to 15% [6]. AMD AR-coating PV glass increases the energy output of photovoltaic modules.

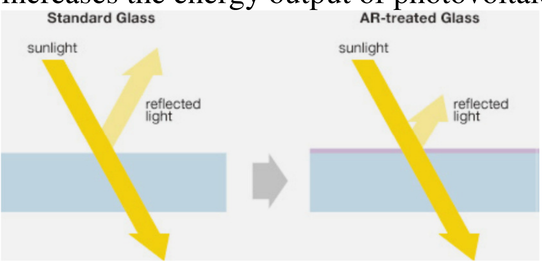


Figure 14. *Comparison between conventional and ar-treated glass.*

Table 4. Proposed electrical generation by using nanomaterial

	Percentage of Energy covered	Cost
National electrical grid	50%	0.03$/KW
Current Q-cell system	50%	0.81$/KW
Proposed Nanosolar system	50%	0.05$/KW

By using the Nanosolar as alternative solar system, with maximizing 2% the efficiency of the current Q-cells system, we can achieve a 100% of energy depending on renewable sources (Table 4).

3.3.2. Thermal insulation: Nanotechnology promises to make insulation more efficient, less toxic. Manufacturers estimate that insulating materials derived from nanotechnology are roughly 30 % more efficient than conventional materials [2]. Insulating nanomaterial may be sandwiched between rigid panels, applied as thin films, or painted on as coatings. In the case study project, we propose Thermablok Aerogel Insulation.

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a) Thermablok Aerogel Insulation blanket (ThAI): ThermablokSP Aerogel is a flexible, nanoporous aerogel blanket insulation that reduces energy loss whilst conserving interior space in residential building applications. It works by breaking the thermal bridging link whilst being totally breathable, ensuring a healthy, durable working building with a natural ability to repel liquid whilst allowing the passage and release of moisture vapour. ThAI is hydrophobic, and is therefore not affected by moisture or age. A single 10mm thickness of ThAI increases the insulation factor by up to 67%.

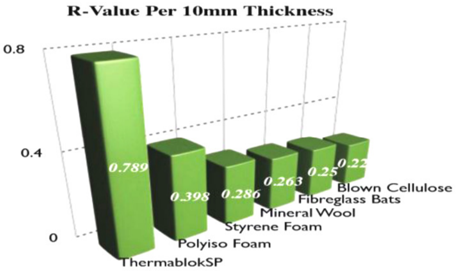

Table 5. Comparison between Thermablock proposed and current EPS used

	Thermablock	EPS
Density (Kg/m3)	150	16-24
Thermal Conductivity (W/mK)	0.013	0.03-0.038
Fire Resistance	Euro Fire Class – Class C-s1,d0.	Moderately flammable
Energy reduction	900 KWhr/yr	

Figure 15: *R value of Thermablock Aerogel with other insulation material.*

ThAI provides the highest R value / lowest U-value of any insulation material for maximum energy efficiency in walls (Figure 15). By comparing the physical characterstics of the Thermablock with the EPS current insulation used in the external wall, the thermal conductivity is twice more efficient (Table 5). Therefore, it estimated to reduce the energy needed to cooling and heating.

b) Nanoseal wet look: This product is used to protect walls from water to overcome the problem of efflorescence and algae / fungus formation on the surface. It can be applied on vertical new or restored surfaces including high porosity concrete (split faced block, brick, adobe, limestone, granite, sand-stone, terra cotta, stuccos, mortar).

3.3.3. Solar protection: Solar protection against heat gain from solar radiation is offered by Low-e glass that can replace the used double clear glass in the opening of the case study project.

a) SOLARBAN 60 Solar Control Low-e Glass: Solarban Solar Control Low-e Glass is a spectrally selective glass option that reduces long (ultraviolet) and short wave (infrared) radiation, and allows visible light to be transmitted through the glass. It can control solar heat gain, which is essential to minimizing cooling costs. With a very good Solar Heat Gain Coefficient (SHGC) of 0.38, Solarban 60 glass blocks 67 percent of the total solar energy while allowing 70 percent of the visible light to pass through. This combination produces an excellent Light to Solar Gain (LSG) ratio of 1.85, along with exceptional insulating performance, as evidenced by its 0.29 winter night time U-value. Corresponding carbon emissions from the building can be reduced by more than 300 tons per year, which eclipses the total carbon emissions generated by 31,000 gallons of gasoline.

Table 6. Performance comparison between As-built system and Nano-retrofitting proposed.

	As-built	Nano-retrofitting	Energy reduction
Energy demand	21,666w/day =7,000 Kwhr/yr	Thermablock insulation + SOLARBAN® 60 Solar Control Glass	18.5% =5,700 Kwhr/yr
Energy supply	Q-cells Solar panel 10,833 w/day= 3,899 Kwhr/yr	AMD AR Nano-coating 2% =4,678 Kwhr/yr	135%
		Nanosolar panel 3,600 Kwhr/yr	

Figure 16*. Project design with the proposed materials and treatment.*

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By using the previous proposed material, generating electricity by the nanosolar panel utility, and ameliorating the existing PV performance by the antireflective coating, the existing building envelope is upgraded to establish an aggressive energy efficiency target that enables us to produce the amount of on-site renewable energy required to reach a net zero carbon emissions footprint of the building.

4. Conclusion: The proposed nanotechnology material can be practical to insure a new Zero carbon architecture; it employs an ecological envelope that is responsive to the site and environment forces; it reduces or eliminates dependence on fossil fuels; it is renewable, and strives for little or no carbon based energy consumption. Referring to our study case, the paper proposes several architectural solutions depending on nanotechnology and nanomaterial. The integrated design of Q-cells solar system is treated with anti-reflective AMD AR Nano-coating, to confront the derivation of the cells orientation and increase the cellsefficiency 2%. To provide the rest clean energy required to reach zero carbon emissions, the research identified on-site renewable energy systems that include 10 Nanosolar panel covered the South and West pitched roof. The new solar system is characterized by a low initial cost comparing with the existing one. Nanoseal wet look is a Nano-product proposed to prevent thewater penetration through the external stone cladding (Figure 16). The external layer of the double clear glass used in the windows and doors, can be replaced by SOLARBAN 60 Solar Control Low-e Glassto block 60% of the solar heat gain through the envelope opening with a high penetration of daylight. The project created a design solution for affordable zero carbon emissions residential building by generating 135% of the energy needed depending on Nano renewable sources (Table 6).

Wider, several recommendations are stated to the private sector, local authorities and Government to reduce the threat of carbon emissions. First and foremost, for the private sector, strategies of raising the level of knowledge and awareness about climate change danger and the new buildings materials technology should be set forward. The local authorities can also take steps forward in this domain. The guidelines for sustainable developments should be integrated in the Lebanese construction law. Nonetheless, they should ensure that, at least, public projects ought to use energy efficient and environmentally sustainable components and construction practices. Creating a new green and amenities area in the urban fabric can enhance the community engagement in the Decarbonisation plan. Furthermore, the discounts on new environment friendly materials and green construction technologies such as nanotechnologies can promote importing and using such materials locally, and encourage the scientific research focusing on nanotechnologies.

REFERENCES:

[1] A. Smith and G. Gill, (2011). Toward Zero Carbon: The Chicago Central Area DeCarbonization Plan, The images Publishing Group Pty Ltd.

[2] G.Elvin, (2007) Nanotechnonoly for Green Building, Green Technology forum.

[3] Fouad Hamdan, (1998). greenpeace mediterranean - background information industrial pollution in lebanon.

[4] Guzowski Mary, (2010). Towards Zero-energy Architecture: New solar Design, Laura King Publishing Ltd.

[5] Adel Mourtada, (2009). Solar Thermal Insulation Market in Lebanon .

[6] L.Sylvia, (2008). Nano materials in architecture, interior architecture and design,Birkhauser Verlag, Germany.

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Planning outline and analysis of actual energy operational performance from completion to present in Japanese and foreign large domes and stadiums‐Tokyo Dome, Fukuoka Dome, Odate Dome, Sapporo Dome, Kaohsiung Stadium –

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Abstract Summaryt: *The authors have been planning, designing, supervising, and verifying domes and stadiums for over 20 years. These buildings were designed as local sports facilities or multi-purpose facilities for large audiences.*

These facilities have individual characteristics reglecting their regions. Design intentions and methods of environmental planning have changed with the times, and actual energy consumptions levels vary with the type of events and number of event days.

We compare these domes and stadiums from environmental perspective, and analyze the operational improvement and energy management performance. We believe that such case studies have not previously been conducted.

We analyze the methods of these domes and stadiums, with respect to load reduction, natural energy utilization, energy systems, and renewable energy. We compare and analyze the reduction rates of actual energy data from completion to the present, and discuss the mention the issues concerning environmental planning of large-scale domes and stadiums in the future.

Keywords: ***domes and stadiums, Japanese and foreign countries, environmental planning, annual actual energy consumption and visitors***

1. History of Japanese large domes and stadiums

After the 1980s in Japan, city stadiums and sports facilities were ready for replacement, and several plans for all-weather and multi-purpose stadiums were proposed. Becouse they would allow sporting events and exhibitions to be held on rainy days, large domes projects were also proposed. In addition, inner domes were constructed in the U.S.A., membranes with high degrees of weather resistance, transparency, strength, fire resistance were developed, and the national building standard law was developed, special certification by the minister of construction was introduced. Tokyo Dome was completed in 1988 as the first air-supported dome in Japan. In the early 1990s, dome projects retractable roofs as the new attraction were

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proposed. Fukuoka Dome was completed in 1993 as a large retractable roofs dome. In the 1990s midium-size domes for local governments were actively proposed. Regionally specicific development, such as the use of local wood and natural energy was also proposed, with Ohdate Jukai Dome as one example. The determination of the World Cup would be held in Japan in 2002 led to planning in Japanese various cities of football stadiums meeting the FIFA standard of natural grass. Football stadiums with full roof were planned in Sapporo and Ohita. Now that the Tokyo Olumpics of 2020 determined, plans for a new National Stadium and other arenas are in progress.

2. Features of domes and stadiums designed by authors

2-1. "Large space as an artificial environment" / Tokyo Dome

This was the first air-supported dome in Japan. Air pressure supports the membrane roof with steel wire reinforcement. The dome controls air pressure, increasing the pressure during high winds, snowfall, exit of the audience, and evacuation. Evacuation is carried out for maintenance of the membrane roof, and in case of emergency such as fire. The pressuring capacity has been maintained for a long period of time. Environmental planning features includes the cooling and heating of the seats each level; the maintenance of natural lighting from the membrane roof; and the minimization of air leakage. Minimization of air leakage is intended to minimize the operating costs.

Fig-1 Tokyo Dome / Interior photo

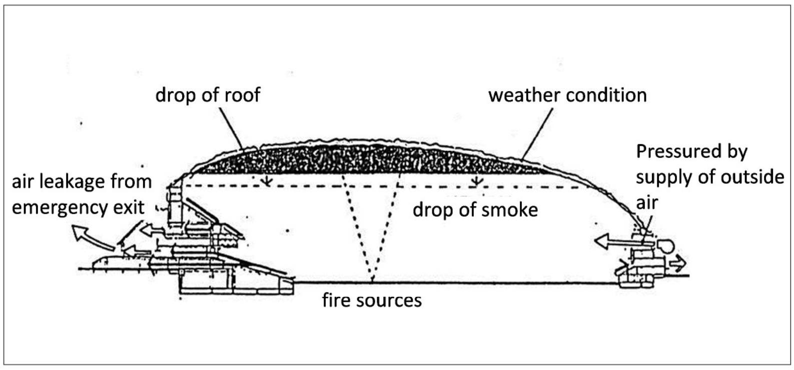

Fig-2 Roof keeping and accumulation of smoke in case of emergency

2-2. "Large space convertible between indoor and outdoor" / Fukuoka Dome

This dome was planned in Fukuoka for multi-purpose use, such as baseball, concerts, and exhibitions. It was the first dome to incorporate large retractable roofs. Roof opening and closing still continues today. Environmental planning features include the placement of the field to maximize the sunshine; the selection of weather conditions to determin whether the roof should be open or closed; verification of airflow and temperature during roof opening; the determination of air flow through the stands by the circulating flow fans; and the consideration of rainwater reuse.

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Fig-3 Fukuoka Dome / Interior photo

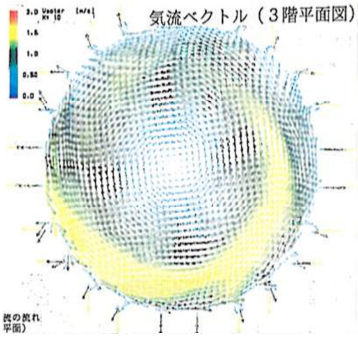

Fig-4 Air flow in stands by circurating flow fans

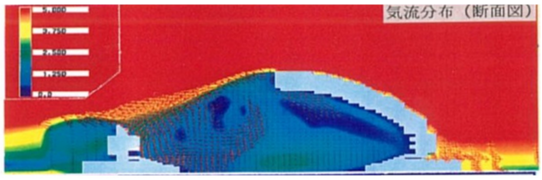

Fig-5 Air flow CFD at roof opening

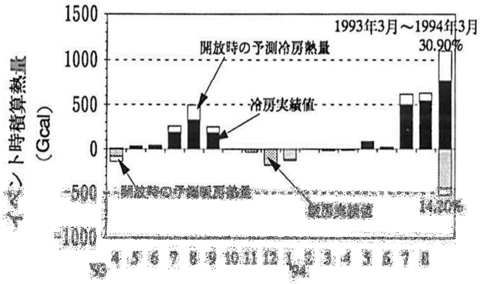

Fig-6 Monthly arena cool load & heat load and effect of retractable roof ('93.4-'94.8)

2-3 "Local sports dome using natural energy and local materials" / Odate Jukai Dome

This dome is located at Odate in Akita prefecture, and has a hybrid structure of wood and steel. It was planned as a core facility for sports promotion in the region, as well as for use of local citizens. Environmental planning features include conservation of the site's forest; the use of local wood; maximum use of natural ventilation and daylight; outside air introduced from the pond side; heating of the bench seats, and reduced life cycle environmental impacts.

Fig-7 Odate Jukai Dome / Interior photo

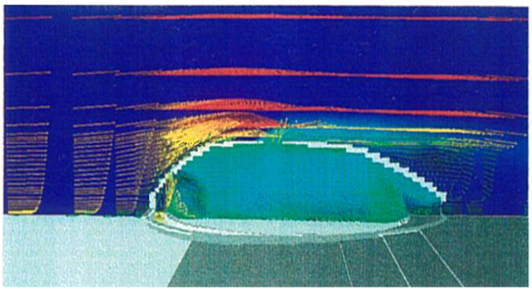

Fig-8 Airflow CFD / Natural ventilation

2-4 "Large space with summer and winter modes in cold/snow region" / Sapporo Dome

This is a large dome in a cold and snowy region. It is the city's facility for baseball, soccer, concerts, and exhibitions. Many events can be held even during the cold and snowy season. The natural grass stage moved to the field for soccer games. The large openings utilize natural ventilation and daylighting, and work together with exhaust openings and top light in the roof top. Environmental planning features include insulation and air tight; thermal storage; seat air conditioning using slit openings; the design of air flow through trench, stand slab, air chamber, large space, and finally the roof exhaust opening; geothermal heat in the trench; well water use and rainwater reuse. An energy management strategy was necessary to increase the operation of natural ventilation and reduce use of the heat source.

Fig-9 Sapporo Dome / Interior photo

Fig-10 Interior photo at moving wall open

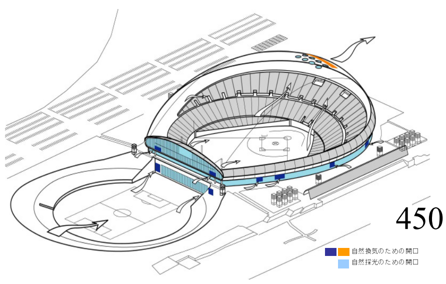

Fig-11 Diagram of air flow at natural vent.

2-5. "Open Stadium that generates energy"/ Kaohsiung Stadium

This is an outdoor stadium in the southern region of Taiwan. It is planned as an international athletics stadium. The form is open on the main station side. The lower level of the stands is also open to the inner field and outer facade, and the canti-lever roof covers the stands. This shades the stands, improves air flow, and provides light illumination at night. See-through photovoltaics panels form a roof that covers the stands.

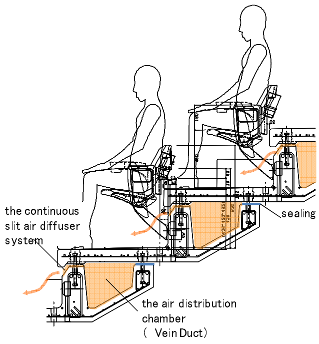

Fig-12 Sapporo / air diffuser system

Fig-13 Kaohsiung Stadium / Exterior photo

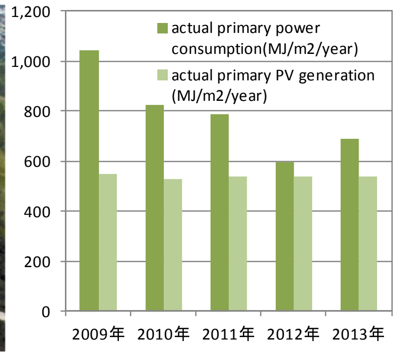

Fig-14 Power consumption & PV generation

2-6. Design intent and method

It is important in the planning of domes and stadiums that the collaboration between building design, environmental design, and MEP design occurs in the early stage. It is also important to study the planning the placement of the stadium, section, external shape, and the placement of the openings, considering the district temperature, humidity and wind direction. Maintenance of the thermal environment, air flow around the stands and seats, and ensuring an adequate supply of daylight are also important.

2-7. Methods of reducing the environmental load

Several methods exist to reduce the environmental loads of domes and stadiums. These include the lighting load by daylight; occupied zone air conditioning to primarily target the stands and field; cooling load reduction by natural ventilation; use of the heat storage of the stands and floor for maintenance of the thermal environment; reduction of potable water consumption by rainwater and wastewater reuse; and reduction of the lighting and air conditioning loads due to the outside of the arena. Air conditioning accounts for a large proportion of an indoor stadium's load. It is necessary for cooling and heating to be in accordance with cold weather to provide heating and ventilation for the audience.

2-8. Local climate and large space

Tokyo and Fukuoka are located in warming areas, whreas Sapporo and Odate are located in cold areas. Kaohsiung is hot and humid all year round. In each case, the insulation, air-tightness, use of natural ventilation are different. And wind direction in the district is also different. In Fukuoka Dome the orientation of the roof opening and the axis of the back net/screen are defined by the effects of shade and the external wind. In Odate Dome, the placement of the pond was determined by the outside air introduced from the main wind direction. In Sapporo Dome, the openings of the movable wall are determined by the main wind direction, and insulated or airtight lines are carefully chosen. In Kaohsiung Stadium, it

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was planned that the prevailing wind will flow through the audience, and the roof of the canopy was installed accordingly.

3. Study on actual management performance and energy consumption of domes

3-1. Ensuring the attraction, repeaters, and various events

Tokyo Dome, Fukuoka Dome, and Sapporo Dome are located in large cities. Events are divided mainly between the baseball season and the off-season. Dependings on the dome and particular year, the number of days when events were held (except for construction, removal, and practice) has reached 130 to 220 days per year. During baseball season, franchise baseball teams hold professional games 30 to 75 days a year. Baseball games of other teams and intercity baseball games etc. are also held. In Sapporo Dome, franchise soccer team had done approximately 10 games per year. American football games and the like are also occasionally held in each dome. In the off-season, exhibitions have become annual events. A few concerts have also been held. For artists and event promotion companies, these are very important event. Odate Dome is an all-weather facility aimed at regional development, with a focus on sports. The major events are tournaments for Akita prefecture and Odate city. The number of annual users is approximately 20 million, and the number of days used is stable at over 300.

Students and sports fans in the region have become regular attendees of the dome.

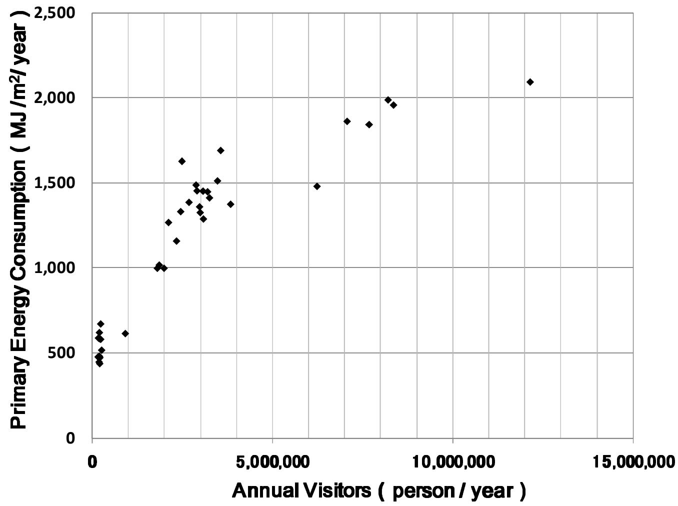

Fig-15 Annual visitors and primary energy consumption

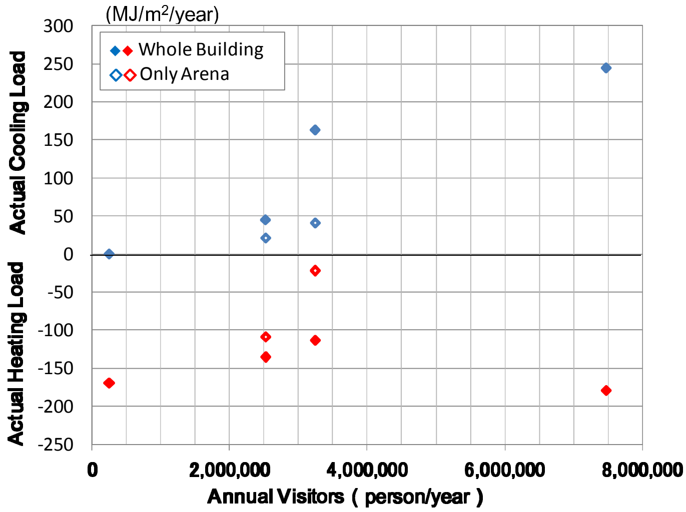

Fig-16 Annual visitors and cooling load / heating load

3-2. Actual primary energy consumption

Figure-15 shows the results of the survey for primary energy consumption of the entire building, and the annual number of visitors. If the number of visitors increases, the primary energy consumption also tends to increases. However, if the number of visitors is very large (on the scale of several million people), energy consumption per unit area tends to level off.

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For a local dome, the annual number of visitors is only a few hundred housand. The primary energy consumption is small, approximately 500MJ/m2/year.

3-3. Actual cooling and heating load

Figure-16 shows the results of the survey for the cooling and heating loads and the annual number of visitors. If the number of visitors increases, there is a tendency that the cooling load also increases. The rate of air conditioning to the overall consumption is as high as 50%; the effect on energy consumption is large. In the two domes, the arena air-conditioning line is measured individually. For the reason that operating hours for arena is short, the ratio of arena cooling and heating load to all loads is not particularly high. In Odate Dome, the cooling load is zero because there is no cooling system; meanwhile, the heating load per unit area is at the same level as the other large domes.

3-4. Effects and actual results of natural utilization

Natural energy utilization, (such as the use of daylight, natural ventilation, etc.) is very effective in domes and stadiums.

With regard to daylight, the stadiums use different methods, such as daylight from a membrane roof (Tokyo, Odate); daylight from retractable roofs (Fukuoka); daylight from top light and movable wall openings(Sapporo); and an outdoor environment(Kaohsiung). It is very important for sports domes and stadiums to provide natural light to athletes and the audience.

Natural ventilation is impossible in Tokyo Dome, because it is an air supported dome. Meanwhile, the powers of exhaust fans are very few for same reason. Air leakage volume for the closed state is approximately 150,000 m3 /hour and has not changed since completion. The percentage of annual energy consumption by air pressured fan power is only 2.2%. In Fukuoka Dome, the arena is exposed to outside air when the roof are open. In Odate Dome, we installed openings in the exterior wall and roof, and actively planned natural ventilation. Kaohsiung Stadium is an outdoor stadium, and it is planned to utilize natural ventilation between the front and rear of the stands.

With regard to renewable energy, photovoltaic(PV) panels were recentry installed in Sapporo Dome. The 1 MW solar installation in Kaohsiung stadium is remarkable. See-through PV panels were installed over the entire stand area considering access to natural light and views of the sky. The generated power is consumed at the stadium, and the extra power is sold to the power company. The annual generated power is slightly less than the current power consumption, but nearly balanced. Consumption of this stadium is rather low, nearly achiving a zero energy stadium.

With regard to the actual effects, in Fukuoka Dome, lighting consumption was reduced by 20% and the cooling load was reduced by 31% one year after completion. In Odate Dome lighting consumption was reduced by 69% with membrane daylighting, and the cooling load was reduced by 92%. In Sapporo Dome Naturalventilation was in operation 75 to 82% of the time, and cooling load was reduced 83% by the use of natural ventilation, night purge, and geothermal cool trench. Kaohsiung Stadium is an outdoor stadium, and the air conditioning load and daytime lighting power consumption are zero.

3-5. Maintenance and replacement

Maintenance is commissioned to a company or department professional. The averall consumption and subdivided energy consumption are monitored continually. Each dome analyzes the effects of annual visitors, additional events, the impact of a mild/cold winter and hot / cool summer, and the power saving and generator operation after 3.11 Japan Earthquake. Each dome has improved a plan for the next year. In Tokyo Dome the heat sources, the air pressure control system and the building automation and control system etc. have already been replaced. Each dome is now studying arena lighting system replacements utilizing advanced LEDs.

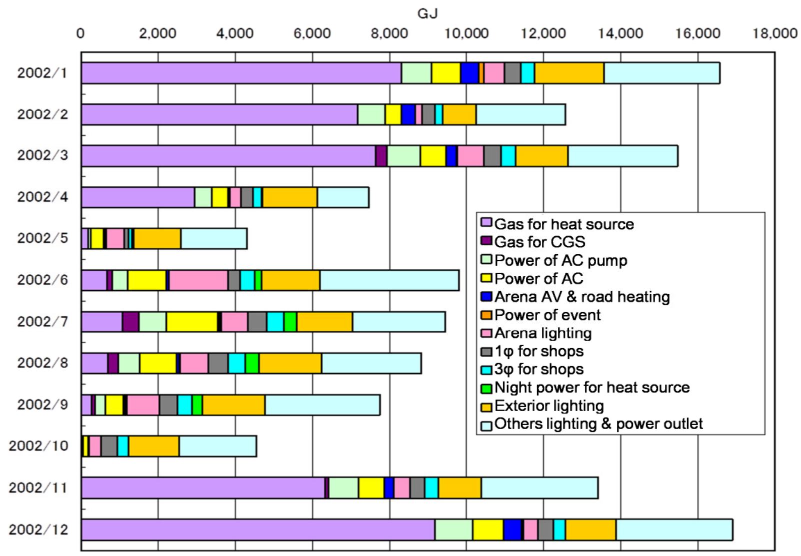

Fig-17 Sapporo Dome / Monthly energy consumption (divided items)

4. Future issues and environmental planning in large audience and scale domes/stadiums

With regard to issues in large audience and scale domes/stadiums in the future, we believe the followings. Planning 20 to 50 years ahead, we emphasize design that is intimate to the district landscape, in harmony with the natural characteristics of the local area, and conductive to diversity of more events and more local people. It is necessary to create facilities that transmit local culture.

With regard to environmental planning, the introduction of advanced technology is expected because of various development, such as greater opening to the outdoors, and increased utilization of natural energy, and generative energy. Because the site and the building area are large, they provide an easy way to generate energy. It is expected that district carbon neutrality initiatives or zero energy stadiums will advance this trend. If there are such opportunities, we would like to participate in the future.

【References】 1)System planning and installation of Tokyo Dome(parts1,2,and 3),1990.Jan, Apr, May, SHASE 2)Air conditioning and plumbing systems of Fukuoka Dome, 1995.Dec.,SHASE 3)Environmental planning and installation of Odate Jukai Dome, 1999, Nov.,SHASE 4) Planning and implementation of environmental system and airconditioning in Sapporo Dome, 2004, Oct.,SHASE

【Special Thanks to】 Tokyo Dome Corporation, Fukuoka Softbank Hawks Corp., Odate Jukai Dome, Sapporo Dome Co.,Ltd., Asahi Facilities.Inc., Richy Liu & Associates, Kaohsiung National Stadium

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Post-Occupancy Evaluation of Green Mark-Rated Buildings in Singapore

Speakers:
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Abstract: *This paper reports on the post-occupancy evaluation of 11 office buildings in Singapore with the intent of evaluating the influence of Green Mark, Singapore's green building assessment tool. Of the buildings, 8 are Green Mark-rated, 3 are not. Each was documented and compared with the others in terms of energy use, indoor environment and occupant well-being. Two findings are reported here. First, there is a large observed variance in occupant density – by a factor of 4.6 – which is not accounted for in the energy efficiency index, as calculated. When this variance is factored into the index, the difference between rated and non-rated buildings narrows significantly. Second, there is widespread non-compliance with the code for operative temperature which, in all buildings, was lower than what is prescribed. These findings are discussed for their implications on energy and well-being, and how Green Mark might, in future versions, become a stronger policy instrument.*

Keywords: Singapore, Green Mark, building assessment tool, post-occupancy evaluation

Background

Launched in 2005 Singapore's Green Mark (GM) set out to raise the bar in the local building sector. GM is administered via a structure of credits that, when aggregated, offer a project one out of four tiers of rating that reflects its performance in terms of energy and water use, and indoor environmental quality (IEQ). Many of the baseline requirements and criteria in GM correspond with national codes and guidelines; the tool therefore serves to encourage building teams to go beyond code. In 2008 it became mandatory for all new buildings in Singapore to be, at minimum, compliant with the lowest tier of certification. At the start of 2014, there were some 1800 buildings certified, accounting for 20% of all buildings in Singapore. By 2030 Singapore aims to have 80% of its building stock certified.

As a national policy instrument GM has long term goals and is subject to continuous review. The Building Construction Authority of Singapore (BCA) – which owns and administers GM – commissioned this study in 2008, seeking post-occupancy data from certified buildings with the goal of strengthening future versions of the tool. This paper reports two key findings.

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The first relates to the metric that is applied to the calculation of energy efficiency. The second concerns occupant well-being as it relates to the indoor thermal condition.

Methodology

The 11 office buildings were selected on the basis of the following criteria:

a. Equal representation from all tiers of GM certification (2 each)
b. All buildings to have a minimum 12-month occupation
c. All buildings to be about the same age (<3 years)
d. All buildings to be predominantly office use

A selection was made from all available certified buildings in 2009, four years into the launch of GM. Due a shortage of case studies, 2 of the buildings selected were certified under the Existing Building category – i.e. they are older than the rest – and 3 were reliant on district cooling system (DCS) which meant that the energy load for cooling could not be easily isolated (see Table 1).

	GM Tier	GM Category	Year of Completion	Total Floor Area (m^2)	Population (excluding visitors)	District Cooling System (DCS)	Number of occupants surveyed
Building 1	Platinum (P)	New	2009	30,800	2,100	Yes	529
Building 2	Platinum	New	2009	33,599	1,596	No	139
Building 3	Gold Plus (GP)	New	2009	14,358	400	No	322
Building 4	Gold Plus	New	2009	11,520	636	No	163
Building 5	Gold (G)	Existing	2002	186,886	8,000	No	201
Building 6	Gold	New	2008	15,235	374	Yes	180
Building 7	Certified (C)	Existing	1985	34,736	1,650	No	67
Building 8	Certified	New	2009	9,481	544	No	88
Building 9	Non-Certified (NC)	New	2008	119,139	4,372	Yes	161
Building 10	Non-Certified	New	2004	56,220	4,814	No	162
Building 11	Non-Certified	New	2005	29,408	500	No	191

Table 1 – Summary of buildings selected

The energy performance of the buildings was described with the energy efficiency index (EEI)[1] that is prescribed in GM, relying on data from utility bills. Water consumption data was also collected, however, there is no known index for water efficiency and it proved

[1] EEI = [(TBEC-DCEC)/(GFA-DCA-GLA*VCR)]*(NF/OH)

a. TBEC : Total building energy consumption (kWh/year)
b. DCEC : Data energy centre consumption (kWh/year) (If not known, estimate at 540m2, 168hrs/week)
c. GFA: Gross floor area (total area excluding carpark and datacentre) (m2)
d. DCA : Data centre area (m2)
e. GLA : Gross lettable area (m2)
f. VCR : Weighted floor vacancy rate of gross lettable area (%) = 1-occupancy rate
g. NF : Normalising factor based on typical weekly operating hours that is 55hrs/week
h. OH : Weighted weekly operating hours (hrs/week)

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difficult to make a meaningful comparison. Twelve IEQ variables[2] were measured on-site over several days per building. An instrument trolley – custom-built for the study – was brought to three locations per floor, three floors per building. Over 2200 randomly selected occupants were surveyed on the same floors. The survey consisted of 46 questions including perception of comfort, productivity and health. Responses on perceived comfort, thermal sensation and adaptive behaviour are reported here.

Energy

Observed EEIs are summarised in Table 2. This excludes Building 8 for which energy figures were not made available and three other buildings – 1, 6 and 9 – which rely on district cooling systems (DCS).

As a group, GM buildings have a weighted average of 152.8 kwh/m^2/yr. This is 27.9% lower than for non-GM buildings, 212 kwh/m^2/yr. It is noteworthy that the average for non-GM buildings in this study is not too far from an earlier benchmark for Singapore office buildings: 231 kWh/m^2/yr (Dong B., Lee S.E. and Sapar, M.H., 2005). Against that figure, the GM group in this study is 33.9% better.

Building	GM Tier	Gross Floor Area (GFA, m2) = Total-[carpark+ datacentre]	Popu-lation	Total Energy Use (kWh) for a 12 month period, excluding datacentre	Observed EEI (kwh/m2/ yr) based on total energy use	Observed EEI, weighted average by GM tier (kwh/m2/yr)	Observed EEI, weighted average GM vs non GM (kwh/m2 /yr)
Building 2	P	33,496	1,596	2,704,554	142	142	152.8
Building 3	GP	14,358	400	1,862,120	119	156	
Building 4	GP	11,520	636	1,568,553	203		
Building 5	G	181,500	8,000	34,431,535	152	152	
Building 7	C	29,363	1,650	8,981,750	167	167	
Building 10	NC	48,139	4,814	15,282,486	269	212	212.0
Building 11	NC	23,208	500	2,842,468	94		

Table 2 - Observed EEI of buildings (excluding building 8 and the DCS projects)

In the course of the building visits, it was observed that some were more densely populated than others. This is found to range from 10 to 46 m^2/person, a factor of 4.6. The mean weighted average of population density across all buildings is 22 m^2/person.

[2] Singapore building guidelines for indoor environment includes standards for Operative Temperature, Relative Humidity, Air Velocity, Carbon Dioxide, Carbon Monoxide, Formaldehyde, Total Volatile Organic Compounds, Respirable Suspended Particles, PM4, Bacteria, Mould, Sound, Illuminance

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Table 3 examines variance of population density (m^2 per person) in 10 buildings.

Building	GFA (m2)	Population	Density (m^2/p)
Building 10	48,139	4,814	10
Building 1	21,167	2,100	10
Building 4	11,520	636	18
Building 7	29,363	1,650	18
Building 2	33,496	1,596	21
Building 9	92,505	4,372	21
Building 5	181,500	8,000	23
Building 3	14,358	400	36
Building 6	14,930	374	40
Building 11	23,208	500	46

Table 3 - Population densities of all buildings (excluding Building 8)

Table 4 shows EEI*, which is EEI modified to account for population density[3].

<table>
<tr><th>Building</th><th>GM Tier</th><th>Observed EEI (kwh/m²/yr) based on 12 month utility bill</th><th>Population Density</th><th>EEI* (kwh/m²p/yr</th><th>EEI* (kwh/m²p/yr weighted average by GM tier</th><th>EEI* (kwh/m²p/yr weighted average GM vs non GM</th></tr>
<tr><td>Building 2</td><td>P</td><td>142</td><td>21</td><td>136</td><td>136</td><td rowspan="5">154</td></tr>
<tr><td>Building 3</td><td>GP</td><td>119</td><td>36</td><td>194</td><td rowspan="2">182</td></tr>
<tr><td>Building 4</td><td>GP</td><td>203</td><td>18</td><td>166</td></tr>
<tr><td>Building 5</td><td>G</td><td>152</td><td>23</td><td>157</td><td>157</td></tr>
<tr><td>Building 7</td><td>C</td><td>167</td><td>18</td><td>135</td><td>135</td></tr>
<tr><td>Building 10</td><td>NC</td><td>269</td><td>10</td><td>122</td><td rowspan="2">147</td><td rowspan="2">147</td></tr>
<tr><td>Building 11</td><td>NC</td><td>94</td><td>46</td><td>198</td></tr>
</table>

Table 4 - EEI (excluding Building 8 and the DCS projects)*

The weighted average EEI* for GM and non-GM buildings is 154 kWh/m^2/yr and 147 kWh/m^2/yr respectively, only 4.5% apart. This is significantly different from the 27.9% difference for observed EEI.

Indoor Environmental Quality

Of the twelve IEQ variables measured, no significant differences were observed between GM and non-GM buildings. All buildings are generally compliant with Singapore codes and guidelines for indoor environment with the exception of operative temperature (T_{Opt}).

[3] To get EEI*, the EEI of a building is multiplied by its population density (i.e. giving energy per person per year). This figure is then divided by a population density factor (PDF). The PDF is the weighted average area per person for all buildings surveyed, i.e. 22m^2/p.

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Figure 1 shows T_{Opt} for 10 buildings. With the exception of Building 5, the 25-75 percentile box of each building is below the lower limit prescribed by the code.

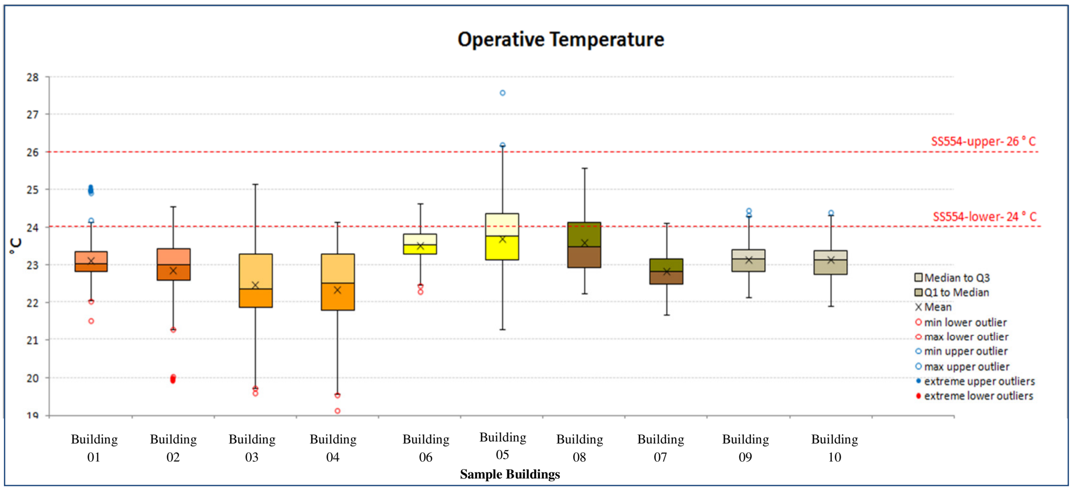
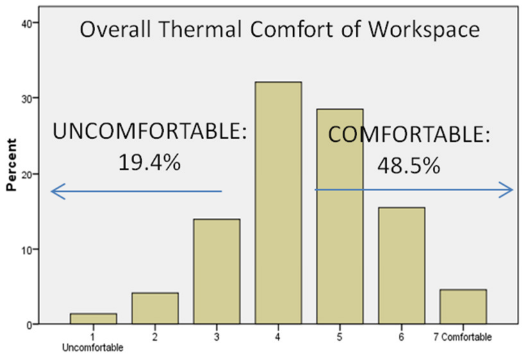


Figure 1 - IEQ measurements: operative temperature of all buildings

This overcooling is cross-referenced with occupant feedback. Figure 2 shows response to the question on perceived thermal comfort. The percentage of people who say they are comfortable (48.5%) is more than twice those that are uncomfortable (19.4%). Figure 3 shows responses to the question on thermal sensation. A respondent is 2.3 times more likely to say s/he is 'cool' to 'too cold' than 'warm' to 'too warm'.



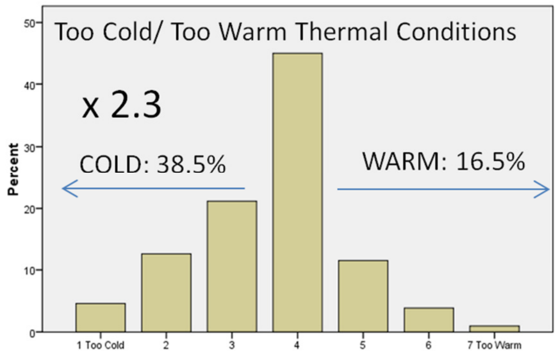


Figure 2 (left) - Survey: overall thermal comfort | *Q: Rate the overall thermal comfort of the building you are in*
Figure 3 (right) - Survey: thermal sensation | *Q: Describe the general thermal condition in your workplace*

To account for the discrepancy between comfort and sensation, the analyses looked to recurring adaptive behaviours. The most frequently cited is 'using an extra layer of clothing'. Seventy three percent of all surveyed say they keep an extra layer in the office with them. It is likely that any thermal discomfort, arising from thermal sensation, is masked by this adaptive behaviour.

Summary of Findings

1. Energy efficiency: GM buildings, as a group, seem to be on average 27.9% more energy efficient than the non-GM buildings, and 33.9% lower than an earlier benchmark for

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Singapore office buildings. When population density – which varies by a factor of 4.6 – is factored into the EEI calculation, this margin changes. *It should be noted however that any comparison between GM and non-GM needs a larger sample size of case buildings to be deemed statistically reliable. The finding here therefore is not the difference between GM and non-GM per se; it is the observed variance in population density and its potential impact on EEI.*

2. Indoor Environmental Quality: There is a widespread non-compliance with code for operative temperature. Measurements show that temperatures are typically below the lower limit prescribed by the code. Feedback on thermal sensation affirms this over-cooling – an occupant is 2.3 times more likely to be cold than warm. This does not however translate to a similar degree of discomfort. Seventy three per cent of all occupants keep an additional layer of clothing in the office, the use of which may be masking the effect of over-cooling.

Implications

The findings suggest two immediate measures:

1. Re-examine basis for consumption indices: EEI does not account for population density which, in the buildings surveyed, was found to vary by a factor of 4.6. In the absence of this consideration, buildings with fewer people will seem to perform better.
2. Tackle over-cooling: Enforce higher temperature set-points in air conditioned spaces, in effect ensuring compliance with code.

On the broader note, the findings pose a question: how does the ‘occupant’ factor into the design of better buildings? EEI, for instance, accounts for systemic efficiency and diversity of use but not the actual number of occupants. Low temperature set points affect comfort resulting in adaptive behaviour as a corrective measure. It was found in an earlier study of office buildings in Singapore (Kishnani, 2002) that when temperature set-points were allowed to drift upwards by up to 2.5K, comfort was not compromised and energy savings amounted to 7.1% of chiller demand, 2.9% of overall energy use. Overcooling of Singapore buildings is therefore unnecessary and costly.

The challenge for GM, it could be argued, is to forge a stronger link between decisions made at the drawing board and the building in-operation. Building owners should be obliged to show that their buildings are operated responsibly with appropriate temperature set points, and that that accountability extends to the intensity of energy use, i.e. energy use normalized to size of building *and* number of occupants.

Limits of current study

The study commenced in 2008 when there was not a large pool of certified buildings. The initial shortlist was further shrunk when some building owners denied the research team access. This posed constraints at the time but it also points the way forward for future studies.

1. Only office buildings were included in the sampling. *The same study, repeated in other building types, may yield different results.*

2. It was decided at the onset that the number of buildings would be kept small, focusing on depth of data collected rather than breadth. *A repeat study should include a larger sample size.*

3. Of the eight GM case studies most are new buildings of comparable age, however, two were certified under the 'Existing Building' category, i.e. they are older buildings that have been retrofitted. *With more case studies, a future study may compare buildings in new buildings category with those in the existing building category. With more case studies, a future study may also be in a position to compare buildings with and without DCS.*

References

Building and Construction Authority, Singapore. Green Mark for New Non-Residential Buildings. Retrieved from www.bca.gov.sg

Dong B., Lee S.E. and Sapar, M.H. (2005). A holistic utility bill analysis method for baselining whole commercial building energy consumption in Singapore. Energy and Buildings, Vol.37: 167-174.

Kishnani, N. (2002). Climate, Buildings and Occupant Expectations - A Comfort-Based Model for the Design and Operation of Office Buildings in Hot Humid Conditions (Doctoral thesis). Curtin University of Technology, Perth, Australia. Retrieved from http://espace.library.curtin.edu.au

Kishnani, N. (2012) Greening Asia, Emerging Principles for Sustainable Architecture. FuturArc Publications, Singapore.

Lee, E.L. (2011). The FuturArc Interview. FuturArc*,* 21: 36-41.

Lee W. L. (2013). A comprehensive review of metrics of building environmental assessment schemes. Energy and Buildings, 403-413.

Sapar, M. H and Lee, S.E. (2006). Establishment of energy management tools for facilities managers in the tropical region; Facilities, Vol.23 No.9/10: 416-425.

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Session 33:

To obtain sustainable building, can the same tools be used everywhere?

Chairperson:

Sauer, Bruno

Director Técnico GBCe, socio Bipolaire Arquitectos. Profesor Universidad Europea de Valencia

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Application of CASBEE-City to Various Types of Cities around the World

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Abstract: *Conducting city assessments can help municipalities determine appropriate measures for sustainability. However, most city assessment tools are designed for assessing cities in developed countries, with a particular focus on megacities. This paper describes how an assessment tool for various types of cities worldwide has been adapted from the "CASBEE for Cities" tool, which was originally designed for assessing Japanese cities. First, the tool is validated by assessing whole municipalities in Japan. Generally, in Japan, living standards are higher than the world average and the environmental load is also correspondingly higher. These findings are verified quantitatively by using the tool. To extend the tool's utility beyond Japan, a rapidly developing municipality in Malaysia is assessed to verify the tool's practicality in other types of cities. Assessment data were gathered through interview surveys and used as input to the tool. The results quantitatively show that conditions in the city should be improved.*

Keywords, CASBEE, Foreign City Assessment, Triple Bottom Line, Environmental Efficiency, Public Statistical Information

1. Introduction

As of 2008, more than half of the world's population is living in urban areas; this figure is expected to rise to 70% by 2050. In today's era of cities, more and more cities around the world are making efforts to become more sustainable. Adoption of the Charter of European Sustainable Cities and Towns Towards Sustainability, also known as the Aalborg Charter, has increased awareness of the importance of actions at the city level to create a sustainable society.[1] In recent years, many academic investigations of city assessments for sustainability have been conducted. For example, the GaWC study,[2] Global Cities Index,[3] Global Power City Index,[4] and Global City Competitiveness Index[5] are several well-known city assessment indices. However, most city assessment tools and indices are developed for assessing only domestic cities or are specifically designed for assessing cities in developed countries due to the availability of and access to data for these types of cities. In this study, an assessment tool for cities around the world is developed. Cities of every type and size can be assessed by the tool if the data necessary for assessment are gathered.

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2. Methodology

2.1 Development of an Assessment Tool for Cities around the World

This section describes modifications to the Comprehensive Assessment System for Built Environment Efficiency (CASBEE) for Cities tool (hereinafter, CASBEE-City) to allow for assessment of cities around the world. Originally, the tool was designed for assessing municipalities in Japan.[6,7,8] CASBEE-City assesses whole municipalities in Japan and enables understanding of the actual conditions in each municipality in terms of environmental, social, and economic aspects.

2.2 Assessment for Quality

CASBEE-City calculates each city's score by using a large database in which information on various cities is stored. The database information is modified for use in the tool. Figure 1 and Equation 1 show the assessment methodology and the scoring function for quality. The score for quality is calculated according to a continuous function so that the effect of measures implemented by municipalities accurately reflects the amount of effort. The scoring function should be different for each assessment item in the subcategory to make the effects of city actions become apparent. As a consequence, a cumulative relative frequency (i.e., percentile rank) curve has been adopted as the scoring function for each subcategory and these subcategory results are converted into the overall score. Histograms and graphs are created for each quality subcategory. The score for quality is calculated on this curve by applying weight coefficients to scores in various major, minor, and subcategories. The target city is assessed "relatively," with the percentile score depending on the group being assessed. The assessment group in CASBEE-City is set to "whole municipalities in Japan." In this study, this assessment group has been expanded to assess whole cities around the world. In other words, each scoring function has been customized. To expand the range of each assessment item, public statistical data has been collected from around the world. For practical reasons, rather than using data for only cities, national data are collected. In the original version, city-level data are desirable for creating the scoring function. However, to expand the tool, national-level data are used as averages for all cities in each country, and each scoring function is created as follows.

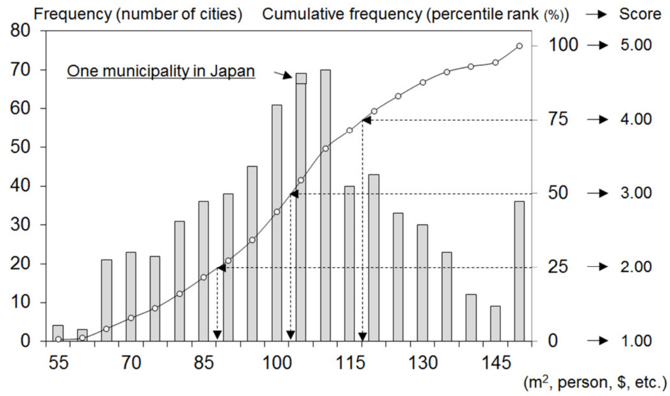

Figure 1. Scoring method for quality

$$Score\ for\ Environmental\ Quality = 25 \times \left[\sum_i \left(\sum_j \left(\sum_k (Q_{ijk} \times w_{ijk}) \right) \times w_{ij} \right) \times w_i - 1 \right] \quad (1)$$

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Each subcategory (Q_{ijk}) is assessed on a five-point scale corresponding to the conditions in a city (higher scores indicate higher sustainability). In Equation 1, w ($0 \leq w \leq 1$) values are category weights, with subscripts corresponding to major (i), minor, (j), and subcategories (k).

Table 1 shows the assessment items for CASBEE-City before and after the modifications for worldwide use. Assessment items in the modified tool should be broadly the same as in CASBEE-City. However, some assessment items have been converted to similar or more suitable items to apply the tool to a broader range of cities rather than just Japanese cities. National statistical data are collected from various organizations, such as the United Nations, World Bank, and World Health Organization, whose statistical data can be considered as

Table 1. Assessment items for quality and load (Upper: original items; lower: modified items)

	Category: Major	Minor	Subcategory (original items)	Assessment item
Quality Q	Q1. Environmental aspect	Q1.1 Nature conservation	Q1.1.1 Ratio of green and water spaces	(Forest area + Major lake area) / Total land area
				No change
		Q1.2 Local environment	Q1.2.1 Air	The number of days which hourly photochemical oxidant concentr
				The average annual exposure level of the average urban resident to
			Q1.2.2 Water	75% of daily average biochemical oxygen demand in a river
				Proportion of the population using improved drinking water source
		Q1.3 Resources recycling	Q1.3.1 Recycling rate of general waste	Recycling rate of general waste
				Municipal waste collected / Total population
		Q1.4 CO_2 sinks	Q1.4.1 CO_2 absorption by forests	Current forest area * unit of absorption (2.92 t-CO_2/ha) / Adjusted
				No change
	Q2. Social aspects	Q2.1 Living environmental	Q2.1.1 Adequate quality of housing	Total floor area per dwelling unit
			Q2.1.2 Traffic safety	Number of traffic accidents / Adjusted population
				Number of road traffic deaths / Total population
			Q2.1.3 Crime prevention	Number of crimes recorded / Adjusted population
				Number of intentional homicide / Total population
			Q2.1.4 Disaster preparedness	Number of disaster response hospitals per 100,000 persons in adju
				Number of hospital beds / Total population
		Q2.2 Social service	Q2.2.1 Adequacy of education service	Number of students at elementary and junior high schools / Numbe
				No change
			Q2.2.2 Adequacy of cultural services	Number of community centres + Number of libraries / Land area o
				Number of Internet users / Total population
			Q2.2.3 Adequacy of medical services	Number of physicians / Adjusted population
				No change
			Q2.2.4 Adequacy of childcare services	Number of childcare facilities / Infant population (aged 0 to 4)
				Number of pre-primary students / Infant population (aged 0 to 4)
			Q2.2.5 Adequacy of services for the elderly	Number of senior care facilities / Senior population (aged 65 and
				Number of nurses and midwives / Total population
		Q2.3 Social vitality	Q2.3.1 Rate of population change due to births & deaths	Rate of increase / decrease in the natural population = Increase / de
				Rate of population change due to births, deaths and migration
			Q2.3.2 Rate of population change due to migration	Rate of population change due to migration = Number of new resic
				(Male life expectancy + Female life expectancy / 2
	Q3. Economic aspects	Q3.1 Industrial vitality	Q3.1.1 Amount equivalent to gross regional product	(Agricultural output + Value of manufactured goods shipments + A
				GDP (Gross Domestic Product) / Total population
		Q3.2 Financial viability	Q3.2.1 Tax revenues	Tax revenues the local government / Adjusted population
				Number of employed persons / Total population
			Q3.2.2 Outstanding local bonds	Real debt service ratio
				Number of unemployed persons / Labor force size
		Q3.3 Emissions trading	Q3.3.1 Amount of emissions trading	Existence or nonexistence of emissions trading
				No change
Load			CO_2 emissions per person	Total CO_2 emissions from each sector / Adjusted population
				Total CO_2 emissions from each sector / Total population

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objective and reliable.

2.3 Assessment for Environmental Load

Equation 2 shows the assessment methodology for environmental load emitted from the target city. CASBEE-City converts the total amount of CO_2 emissions per capita into a score from 0 (good) to 100 (poor).

$$Score\ for\ Environmental\ Load = 100 \times \frac{1}{1+\exp(-aX)}, \text{ where } X=\log 10\ x - \log 10 \mu \quad (2)$$

As in CASBEE-City, CO_2 emissions are converted to a score by using a logistic equation. However, because the range of CO_2 emissions can range from virtually nothing to an extremely large value globally, the assessment range is expanded in the modified tool. Thus, the explanatory variable for CO_2 emissions is converted to a logarithmic scale. Here, a is the gain, which controls the curvature of the logistic curve, x represents the amount of emissions from the target city, and μ represents the present world average emissions amount. Figure 2 shows the curve created by the logistic equation. Two reference points have been set. First, CO_2 emissions equal to the present world average rate is assigned a value of 50 points. When the value of x is 0.94 t-CO_2/person/year, 12.5 points is assigned as a second reference point,[9] which is the point where the target city achieves an 80% reduction over the current world average, in accordance with the long-term target for developed countries.

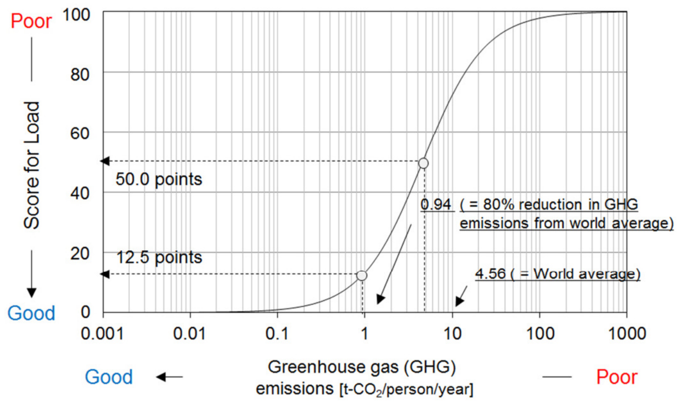

Figure 2. Scoring method for environmental load

3. Results and Discussion

3.1 Reassessment of Whole Municipalities in Japan

Whole municipalities in Japan were reassessed using the modified tool for verification against the prior model. All assessment items must be checked for validity because some assessment items have been changed in the modified tool.

Figure 3 compares the results for the quality of whole municipalities in Japan as assessed by the original and modified tool, using the assessment items in Table 1. The left figure shows the quality scores using the original and modified assessment items. Only small differences in quality scores were observed after assessment items were changed (the slope of the regression line is about 1). The assessment items are also quantitatively verified to some extent because variation of the score differences between the original and modified items are small (the standard deviation of the score differences is about 6.47). The right figure shows the quality

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scores using the original and modified assessment range. “After modified” corresponds to the world assessment range and “Before modified” corresponds to the Japanese assessment range (i.e., from CASBEE-City). All plots are located above the diagonal, in other words, score for whole municipalities were improved after assessment range was expanded. This means that the living standard in municipalities in Japan exceeds the world average (= 50 points).

Figure 4 shows the assessment results for whole municipalities in Japan using the modified tool. The results are shown on a two-dimensional built environment efficiency (BEE) chart in which the vertical axis and horizontal axis show city quality from 0 (worst) to 100 (best) and environmental load imposed by the city from 0 (best) to 100 (worst), respectively. The main contribution of this study is expanding the Japanese assessment scale of the original CASBEE-City tool to be a global assessment scale. For example, a score of 50 points is updated in the world city tool to indicate the world median score instead of the median score in Japan. Almost all municipalities in Japan exceeded 50 points for both quality and load. This means that the living standard in Japanese municipalities exceeds the world average. On the other hand, most Japanese municipalities impose an environmental load greater than the world mean (where 50 points corresponds to 4.56 t-CO_2 annually per capita), so reductions in CO_2 emissions are required.

3.2 Assessment by Field Survey of a Rapidly Developing Municipality in Malaysia

After the modified tool was developed, Putrajaya city (located south of Kuala Lumpur), a rapidly developing municipality in Malaysia, was assessed to test the practicality of the tool. Figure 5 shows an aerial view and photos of the city. A field survey to collect necessary statistical data for assessment was conducted through interview

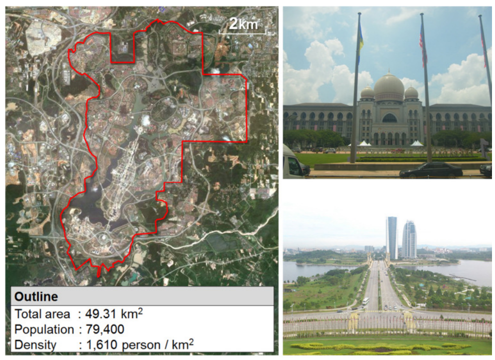

Figure 5. Map and Photos of Putrajaya

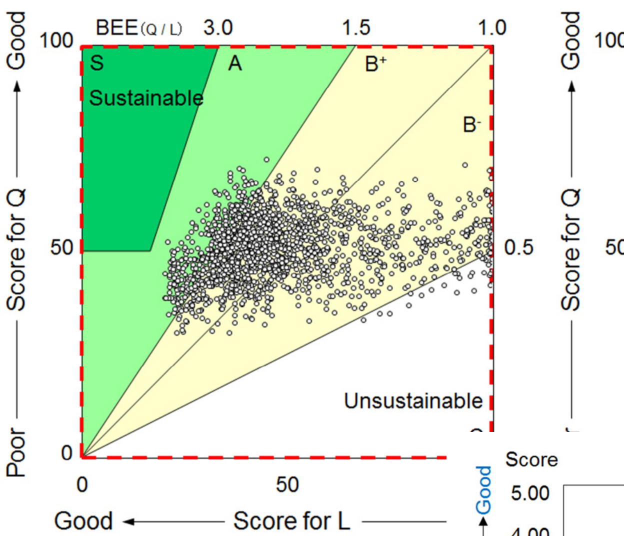

Figure 4. Comprehensive assessment results
(right) tool

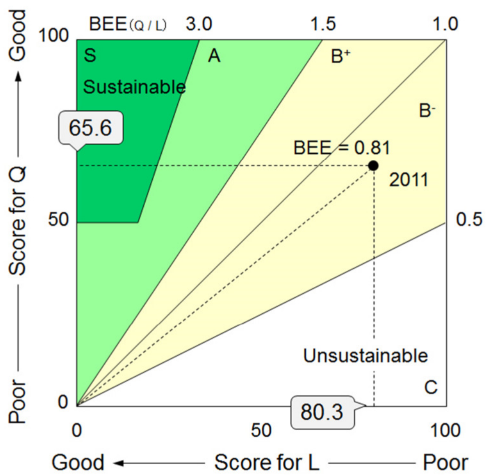

Figure 6 Assessment results of Putrajaya

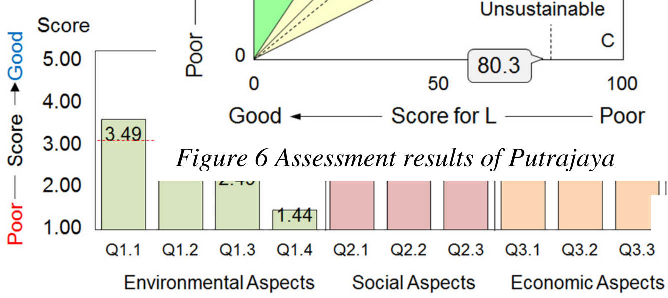

Figure 7. Assessment result for minor assessmnet categories

surveys and input into the tool. However, some data which were not available for the municipality were replaced with Malaysian average values. Figure 6 shows the assessment results for Putrajaya city. The BEE for Putrajaya is currently slightly lower than the world average of 1.0. This result indicates that, from a sustainability perspective, load reduction is more urgent than improvements in quality. Figure 7 shows results on the minor assessment categories shown in Table 1. Almost all scores are higher than the world average of 3.00 points. From Figure 5, it can be seen that lakes and green space are adequate and, as a result, the score for Q1.1 is high. However municipal waste (Q1.3) is being collected by the municipality or a company at less than the world average level. This indicates that implementing waste-related measures should have a higher priority than other environmental measures. It is also necessary to increase amount of CO_2 absorption (Q1.4). In the report "Putrajaya Green City 2025," a total of one million trees are planned to be planted in Putrajaya by 2025.[10] Although this effort has not been quantitatively assessed yet, the score will be drastically improved when the plan is carried out. Social aspects (Q2) of Putrajaya score much higher than the world average. The main cause of the high score for Q2.1 is the high security level of the city. No murders occurred in Putrajaya during the target year. Social services (Q2.2) also scored higher than the world average. The construction of Putrajaya was started in 1995, and almost all governmental functions have been transferred to the city. Many kinds of social functions are sufficient. This transfer of governmental functions also will result in a high score for Q2.3 because the population will be concentrated in the capital. The employment rate is high and unemployment is low in Putrajaya. Although the score is high, many personnel are working in government agencies, rather than private businesses. It should be noted that this employment system is rather unique compared with many other cities, but these assessment results are tentative. To finalize the results, continued cooperation with the local government at Putrajaya is required.

Acknowledgements
We thank the administrative officers in Putrajaya City, whose support and insightful comments were invaluable during the course of this study. We also give special thanks to the Committee for the Development of an Environmental Performance Assessment Tools for Cities (Chair Shuzo Murakami) for providing advice that was essential to the successful conclusion of this study.

References

(1) Aalborg Charter (1994), European Conference on Sustainable Cities & Towns, 'Charter of European Cities and Towns Towards Sustainability', Aalborg, Denmark, 27 May, 1994.

(2) Globalization and World Cities Research Network (2014), The World According to GaWC 2012, [online] (available at: http://www.lboro.ac.uk/gawc/world2012t.html; accessed on 21 May 2014).

(3) A.T. Kearney (2014) ,2014 Global Cities Index and Emerging Cities Outlook, [online] (available at:

http://www.atkearney.com/documents/10192/4461492/Global+Cities+Present+and+Future-GCI+2014.pdf; accessed on 21 May 2014).

(4) The Mori Memorial Foundation (2014) ,Global Power City Index 2013, [online] (available at: http://www.mori-m-foundation.or.jp/research/project/6/pdf/GPCI2013.pdf; accessed on 21 May 2014).

(5) The Economist Intelligence Unit (2012), Benchmarking global city competitiveness, [online] (available at: http://www.economistinsights.com/sites/default/files/downloads/Hot%20Spots.pdf; accessed on 21 May 2014).

(6) Murakami, Shuzo; Kawakubo, Shun; Asami, Yasushi; Ikaga, Toshiharu; Yamaguchi, Nobuhaya and Kaburagi, Shinichi (2011), Development of a comprehensive city assessment tool: CASBEE-City, Building Research & Information, 39(3), pp.195-210

(7) Kawakubo, Shun; Murakami, Shuzo and Ikaga, Toshiharu (2011), Nationwide Assessment of City Performance Based on Environmental Efficiency, International Journal of Sustainable Building Technology and Urban Development, 2(4), pp. 293-301

(8) Kawakubo, Shun; Ikaga Toshiharu, Murakami Shuzo and Asami Yasushi (2013), Environmental performance assessment of municipalities with the “casbee-city” tool, Journal of Environmental Engineering, 683(78), pp. 63-72.

(9) The Committee for the Development of an Environmental Performance Assessment Tools for Cities (2013), CASBEE for Cities (2012 edition) Technical Manual, [online] (http://www.ibec.or.jp/CASBEE/english/download/CASBEE_City_manual_2012 (E).pdf; accessed on 21 May 2014).

(10) Universiti Teknologi Malaysia (2012), Putrajaya Green City 2025, [online] (http://2050.nies.go.jp/report/file/lcs_asialocal/Putrajaya_2012.pdf; accessed on 21 May 2014)

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A Comparison of the Life Cycle Energy Profile of Residential Buildings in Different Countries

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Abstract: *Buildings are responsible for significant energy use and greenhouse gas emissions, globally. Life cycle energy analysis if often used to assess the total energy use of buildings and identify relevant reduction measures. However, most existing studies underestimate embodied energy, do not consider the occupant's transport-related energy and focus on a single country. This study relies on a comprehensive life cycle energy analysis framework to assess three different dwellings in Australia, Belgium and Lebanon. Results show that the life cycle energy profile varies significantly depending on the location and is influenced by a range of factors. This study shows that the proposed method can be applied in different contexts as long as the required data is available. By relying on a comprehensive life cycle energy analysis framework, building designers can prioritise the most effective measures to reduce energy use and ultimately the environmental impact of buildings.*

Life cycle energy analysis; dwellings; different countries; indirect requirements

Introduction

Climate change and global warming are likely to disrupt the lives of millions of people across the world. They are driven by anthropogenic emissions of vast quantities of greenhouse gas (GHG) into the earth's atmosphere at an unprecedented rate [1], the vast majority of which are due to energy use [2].

The operation of buildings alone is responsible for 32% of the final energy use and 19% of GHG emissions, globally [3]. This contribution more than doubles if indirect energy requirements and associated GHG emissions are considered [4]. These include embodied requirements in building materials and the energy required for the mobility of building occupants. Due to this huge impact, buildings yield a large potential for reducing energy use and associated GHG emissions at a global scale.

A life cycle perspective is required to assess energy use in buildings and to identify appropriate strategies for its reduction [5]. This approach ensures that reductions during one life cycle stage are not shifted to another. Life cycle energy analysis (LCEA) quantifies all energy inputs across the different life cycle stages of a process or product.

Most previous studies applying LCEA to buildings suffer from a range of issues. Firstly, they often rely on the so-called process analysis technique to quantify embodied energy. This technique can underestimate embodied energy by up to four times at a whole building level

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[5]. This explains why most reviews of LCEA in buildings, e.g. [6,7], conclude that embodied energy represents only 15-25% of the life cycle embodied and operational energy use over 50 years. Secondly, the vast majority of existing studies focus on the building scale alone ignoring the urban scale, i.e. the transport-related energy use of building occupants and the embodied energy in infrastructures needed to operate buildings. Stephan [4] has established that requirements at the urban scale are often significant. Thirdly, the majority of building LCEA studies focus on a specific case study in a particular country such as Sweden [8]. One of the rare comparative studies was recently undertaken by Mosteiro-Romero et al. [9] who compared the life cycle profile (including a range of environmental impact categories) of a Swiss low-energy house and a US house (in New Jersey). While some reviews compile studies from different geographical areas, they often provide aggregated results and compare studies with different system boundaries. In addition, most existing studies assess buildings in developed economies.

The aim of this paper is to use the same LCEA framework to establish and compare the LCE use profile of new dwellings in different countries and evaluate the applicability of the method in various contexts.

Method

This section provides a summary of the LCEA framework and a brief description of the case studies.

A LCEA framework that comprises all the life cycle stages of the building (except the end-of-life stage) as well as the different scales of the built environment is used in this paper. This framework was developed by Stephan [4] and is described in detail in Stephan and Crawford [10]. Only a summary is provided here.

Primary energy inputs across the following building life cycle stages are taken into account: raw material extraction; material manufacture, processing and transport; construction; and operation and maintenance. The end-of-life stage is not taken into account due to the huge uncertainties about the fate of the building after a very long useful life.

Embodied energy includes the initial embodied energy of the building as-built and the recurrent embodied energy associated with material replacement over its useful life. Embodied energy is quantified using the comprehensive input-output-based hybrid analysis technique developed by Treloar [11]. This technique combines bottom-up process data which are collected from material manufacturers and top-down input-output data that are based on average sectorial energy intensities at a national economy level. Process data is of higher quality, more specific and more reliable but does not cover the entire supply chain due to the difficulty of gathering information for processes further upstream in the supply chain. Input-output data covers the entire supply chain but provides sectorial averages and fails to differentiate accurately between products from the same sector. Hybrid analysis combines both techniques, eliminates their flaws and cumulates their strengths by relying on reliable process data where available and filling the gaps with average input-output data to ensure

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systemic completeness [5,12]. Practically, embodied energy is calculated by multiplying the quantity of each material in the building (based on the material bill of quantities) by a hybrid embodied energy coefficient [13] and the number of replacements over the useful life of the building (including the initial installation). Average material service lives, based on a range of sources, e.g. Ding [14], are used to estimate the number of replacements.

The embodied energy of nearby infrastructure systems (roads, water distribution, gas distribution, electricity distribution and sewage) is taken into account and allocated to the household based on the number of occupants and the average population density in the neighbourhood. This ensures that infrastructure systems that are essential to the operation of a building are considered.

Operational energy includes heating; cooling; ventilation (where applicable); lighting; hot water; appliances and cooking. It is quantified using steady-state heat transfer equations for thermal requirements and regional averages for non-thermal requirements. All final and delivered energy uses are converted to primary energy using primary energy conversion factors based on the energy source and location.

Transport energy requirements include both direct energy (e.g. burning fuel in a car engine) and indirect energy (e.g. manufacturing a car, insurance, registration and maintenance). They are based on the average travel distance per transport mode and per household. Direct energy intensities are based on local figures where available and on Lenzen [15] otherwise. Indirect energy intensities are determined using input-output analysis and are based on Lenzen [15].

The total LCE is the sum of the embodied, operational and transport requirements, over the useful life of the building. It is expressed in GJ/capita in this study in order to take into account the lifestyle of occupants.

This life cycle framework is applied to three different case study dwellings, each typical of recent construction in its country: an energy efficient single family house 25 km west of Melbourne, Australia; a single family passive house 26 km south-east of Brussels, Belgium; and an apartment unit in a four-storey residential building in Sehaileh, Lebanon, 26 km north-east of the capital Beirut. Australia and Belgium are chosen as representative of developed economies (for which the framework was developed) and Lebanon as a developing economy. Table 1 provides a summary of the characteristics of the case study dwellings.

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Table 1: Main characteristics of the three case study dwellings

Characteristics	Australian 7-Star house (AH)	Belgian passive house (BPH)	Lebanese apartment (LA)
Period of analysis (years)	50	50	50
Building useful life (years)	50	50	50
Köppen climate classification	Oceanic climate - Cfb	Oceanic climate - Cfb	Warm Mediterranean climate - Csa
Infrastructure systems	New	Existing	Existing
Gross floor area (m²)	297	330	154
Usable floor area (m²)	267	300	113
Number of occupants	5	4	4
Structure	Timber-framed	Steel-framed	Reinforced concrete
Façade	Brick veneer wall; 100 mm of fibreglass insulation; Double glazed aluminium-framed windows	Glued bricks; 220 mm of polyurethane insulation; Triple glazed, argon-filled, timber-framed windows	Natural stone cover; Double concrete block wall with a 100 mm air gap; Double glazed aluminium-framed windows
Roof	Concrete tiles; 200 mm of fibreglass insulation	Terracotta tiles; 300 mm of polyurethane insulation	Terracotta tiles; No insulation
Finishes	Water-based paint; Nylon carpet in bedrooms; Ceramic tiles in other spaces; Tiled kitchen and bathroom walls	Water-based paint; Parquet flooring in bedrooms; Ceramic tiles in other spaces; Tiled kitchen and bathroom walls	Water-based paint; Ceramic tiles in all rooms; Tiled kitchen and bathroom walls
Average U-value (W/(m²K))	0.58	0.19	1.2
Operational energy sources	Gas heating (eff. 0.7) and cooking (eff. 0.9); Electrical cooling (eff. 2.5); Solar domestic hot water with gas auxiliary system (eff. 0.9).	All electrical: heating (eff. 1.0), cooking (eff. 1.0), ventilation (eff.0.9), domestic hot water (eff. 1.0)	Gas heating and cooking (eff. 0.9); Electrical cooling (eff. 2.5); Electrical domestic hot water (eff. 1.0)
Primary energy conversion factors	Electricity: 3.4[a] Gas: 1.4[a]	Electricity: 2.5[b]	Electricity 3.2[c] Gas 1.1[d]
Cars	2 gasoline[e]	1 gasoline and 1 diesel[f]	2 gasoline[g]
Total car travel distance per year (km)	36 000[e]	32 000[f]	40 000[g]
Total energy intensity of cars (MJ/vkm)	Gasoline: 4.41[i]	Gasoline: 3.2[e, h, i] Diesel: 2.93[e, h, i]	Gasoline: 4.13[i]

Note: eff. represents the efficiency of the end-use system. All average figures for operational energy use are derived from [16] for Brussels, from [17] for Melbourne and are based on [18] for Sehaileh. [a] from[19], [b] from [20], [c] calculated by the authors based on the average electricity mix in Lebanon, [d] assumed, [e] based on data from [21], [f] based on [22], [g] based on an interview of the inhabitants, [h] based on results from [23] and [i] based on [15].

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Results

This section compares the LCE profiles of the case studies and identifies areas of improvement. It provides the basis of the discussion.

Figure 1 shows the LCE profiles of the three case study dwellings, by use. The Australian house (AH) has the highest LCE (4 894 GJ/capita) followed by the Belgian passive house (BPH) (4 833 GJ/capita) and the Lebanese apartment (LA) (4 019 GJ/capita). The LCE of the LA is 20-22% lower than the two other cases. The variation in LCE values results from different contributions from embodied, operational and transport requirements.

The BPH has the highest embodied energy (2 131 GJ/capita; 44% of the total). This is due not only to the significant amount of additional insulation required for the house (see the *Envelope* category in Figure 1) but also to the larger usable floor area per capita, i.e. 75 m², compared to 53.4 m² and 28.3 m² for the AH and the LA, respectively. While the LA has an energy intensive reinforced concrete structure and shares common spaces with other apartments, its embodied energy is two times and nearly three times lower compared to the AH and the BPH, respectively. The small living area per capita and the highly durable nature of construction materials, leading to a small recurrent embodied energy, are responsible for this difference. Note the contribution of the often neglected new infrastructure systems in the AH (242 GJ/capita; 15% of the embodied energy).

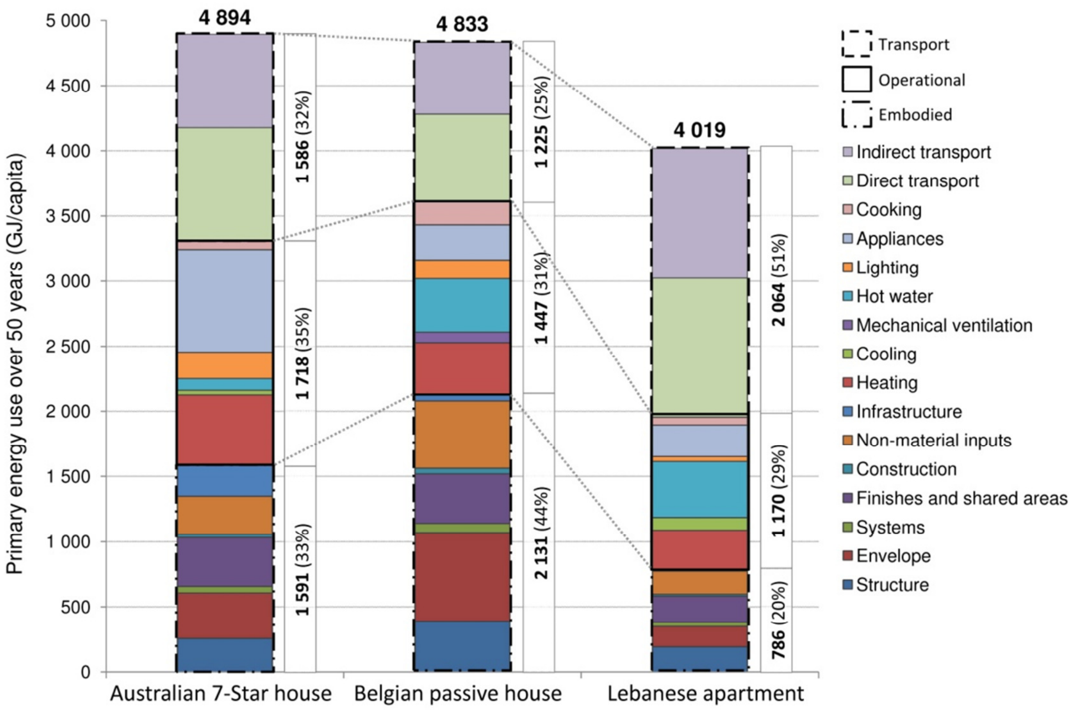

Figure 1: Life cycle energy profile of the three case study dwellings over 50 years, by use.

The AH has the highest operational energy use (1 718 GJ/capita), which is dominated by appliances (46%) and heating (31%). The BPH has a more balanced operational energy use with hot water and heating representing 28% and 27%, respectively, followed by appliances (18%), lighting (12%) and cooking (10%). Operational energy use in the LA is due mainly to

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hot water (37%), heating (26%) and appliances (21%). The installation of solar collectors for hot water could significantly reduce the operational energy use of the BPH and the LA by substituting electricity with a local renewable energy source, as per the AH.

ransport-related energy use is the highest in the LA case (2 064 GJ/capita; 51% of the total) followed by the AH (1 586 GJ/capita; 32% of the total) and the BPH (1 225 GJ/capita; 25% of the total). This results from the larger travel distances in the Lebanese case which are due to the reliance on cars even for proximity trips and the absence of public transport. The suburban location of all the assessed dwellings explains the high contribution of transport-related requirements (25-51%).

Discussion and conclusion

This paper shows that the LCE profile of new dwellings varies significantly between different countries and economies. While the Australian case is the most balanced, with each category representing almost one third of the total, the Belgian and the Lebanese cases are dominated by embodied (44%) and transport (51%) requirements, respectively. This screening allows building designers to identify hot spots in the energy profile and to identify solutions that can yield the most significant reductions. For instance, using energy efficient appliances, selecting a high performance insulation material with a low embodied energy and reducing travel distances while using a fuel efficient car are specific solutions for the Australian, Belgian and Lebanese cases, respectively. Replacing electricity by another fuel source with lower primary energy requirements (such as solar or gas) is a global solution that is relevant to all cases, as highlighted by studies in different countries [8,9]. For example, installing solar collectors for domestic hot water can reduce the LCE use of the BPH and the LA by 3% and 8%, respectively. The 8% reduction (332 GJ/capita) in the LA case is equivalent to the combined energy use for lighting, appliances and cooking, over 50 years. These savings take into account the additional embodied energy required to install and replace solar collectors. This study demonstrates that by adopting wide system boundaries when establishing LCE profiles, the net total benefit of potential solutions can be more reliably assessed.

Apart from establishing the LCE profile of different dwellings, this paper shows that a single life cycle framework can be applied in developed and developing economies. This is possible because specific data, relevant to each case study, can be fed into the framework. The latter provides a sufficient level of abstraction to be transposable to different contexts. Also, by adopting wide system boundaries, the proposed framework is able to capture shifts between life cycle stages or between scales of the built environment (a city-based case study vs. a suburban case study). The proposed framework can be used seamlessly in different contexts as long as the data is available.

However, this study suffers from a number of limitations. Firstly, it relies on Australian data for the calculation of the embodied energy in all cases, due to the unavailability of hybrid data for other locations. Secondly, it uses steady-state thermal energy equations for the determination of thermal requirements, while dynamic simulations can provide more accurate

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estimations. Thirdly, the framework has been applied to three different dwellings, one in each country. A larger sample of dwellings should be assessed to fully evaluate the applicability of the framework. This sample should ideally include existing dwellings, city-based buildings and cases relying on public transport. Fourthly, since the framework is quantitative, it systematically suffers from uncertainty in the data. The latter can greatly hinder the performance of the framework since large uncertainties can be present in embodied energy figures [24], in operational energy figures [25] and in transport energy figures [4]. More robust databases, notably regarding embodied energy requirements, are needed. Finally, this study has focused on energy use only. More environmental impact categories (such as toxicity, ozone depletion and others) should be considered to ensure that environmental impacts are not simply shifted from one category to another.

To conclude, this paper has demonstrated how a single LCEA framework can be applied to case studies located in developing and developed economies. The framework can establish the LCE profile of dwellings. By using this framework, building designers can prioritise measures to reduce energy use and associated greenhouse gas emissions. Future research includes comparing a larger sample of dwellings in different countries and improving the assessment framework to include more environmental impact indicators.

References

[1] IPCC (2013) Climate change 2013: the pysical science basis. Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change. edited by Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M.M.B., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V. and Midgley, P.M. Cambridge: Cambridge University Press

[2] IEA (2012) World energy outlook 2012. Paris: International Energy Agency

[3] IEA (2012) CO_2 emissions from fuel combustion. Paris: International Energy Agency

[4] Stephan, A. (2013) Towards a comprehensive energy assessment of residential buildings. A multi-scale life cycle energy analysis framework. Ph.D. thesis, ULB-BATir - Building, Architecture and Town planning and UoM-ABP - Architecture, Building and Planning, Université Libre de Bruxelles and The University of Melbourne, Brussels.

[5] Crawford, R.H. (2011) *Life cycle assessment in the built environment*. London: Spon Press.

[6] Ramesh, T., Prakash, R. and Shukla, K.K. (2010) Life cycle energy analysis of buildings: An overview. *Energy and Buildings* 42:1592-1600 doi: 10.1016/j.enbuild.2010.05.00.

[7] Cabeza, L.F., Rincón, L., Vilariño, V., Pérez, G. and Castell, A. (2014) Life cycle assessment (LCA) and life cycle energy analysis (LCEA) of buildings and the building sector: A review. *Renewable and Sustainable Energy Reviews* 29 (0):394-416 doi: 10.1016/j.rser.2013.08.037.

[8] Gustavsson, L. and Joelsson, A. (2010) Life cycle primary energy analysis of residential buildings. *Energy and Buildings* 42 (2):210-220 doi: 10.1016/j.enbuild.2009.08.017.

[9] Mosteiro-Romero, M., Krogmann, U., Wallbaum, H., Ostermeyer, Y., Senick, J.S. and Andrews, C.J. (2014) Relative importance of electricity sources and construction

practices in residential buildings: A Swiss-US comparison of energy related life-cycle impacts. *Energy and Buildings* 68, Part A (0):620-631 doi: 10.1016/j.enbuild.2013.09.046.
[10] Stephan, A. and Crawford, R.H. (2014) A multi-scale life-cycle energy and greenhouse-gas emissions analysis model for residential buildings. *Architectural Science Review* 57 (1):39-48 doi: 10.1080/00038628.2013.837814.
[11] Treloar, G.J. (1997) Extracting embodied energy paths from input-output tables: towards an input-output-based hybrid energy analysis method. *Economic Systems Research* 9 (4):375-391
[12] Majeau-Bettez, G., Strømman, A.H. and Hertwich, E.G. (2011) Evaluation of process- and input-output-based life cycle inventory data with regard to truncation and aggregation issues. *Environmental Science & Technology* 45 (23):10170-7
[13] Treloar, G.J. and Crawford, R.H. (2010) Database of embodied energy and water values for materials. Melbourne: The University of Melbourne.
[14] Ding, G. (2004) The development of a multi-criteria approach for the measurement of sustainable performance for built projects and facilities. Ph.D. thesis, School of the Built Environment, University of Technology, Sydney.
[15] Lenzen, M. (1999) Total requirements of energy and greenhouse gases for Australian transport. *Transportation Research Part D-Transport and Environment* 4 (4):265-290
[16] IBGE (2010) Bilan énergétique de la région de Bruxelles-Capitale 2008. Brussels: Institut Bruxellois pour la Gestion de l'Environnement
[17] DEWHA (2008) Energy use in the Australian residential sector 1986-2020. Canberra: Department of the Environment, Water, Heritage and the Arts
[18] Ruble, I. and El Khoury, P. (2013) Lebanon's market for domestic solar water heaters: Achievements and barriers. *Energy for Sustainable Development* 17 (1):54-61 doi: 10.1016/j.esd.2012.11.004.
[19] Treloar, G.J. (1998) A comprehensive embodied energy analysis framework. Ph.D. Thesis, School of Architecture and Building, Deakin University, Geelong.
[20] RBC (2008) Arrêté du gouvernement de la région de Bruxelles-Capitale déterminant des exigences en matière de performance énergétique et de climat intérieur des bâtiments. In *Paper 2008 — 326*, Edited by Ministère de la région Bruxelles-capitale. Brussels: Moniteur Belge.
[21] BITRE (2011) Population growth, jobs growth and commuting flows in Melbourne. In *Melbourne, Report 125*. Canberra ACT: Bureau of Transport, Infrastructure and Regional Economics
[22] Bureau Fédéral du Plan (2012) Transport routier. Edited by BFP. Brussels.
[23] Jonson, D.K. (2007) Indirect energy associated with Swedish road transport. *European Journal of Transport and Infrastructure Research* 7 (3):183-200
[24] Wang, E. and Shen, Z. (2013) A hybrid Data Quality Indicator and statistical method for improving uncertainty analysis in LCA of complex system – application to the whole-building embodied energy analysis. *Journal of Cleaner Production* 43 (0):166-173 doi: 10.1016/j.jclepro.2012.12.010.
[25] Topouzi, M. (2011) The effect of 'default user' inputs in modelling tools and methods in energy use. *Proceedings of 27th International Conference on Passive and Low-Energy Architecture*, Louvain-la-Neuve, 15.07.2011.

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Tomorrows buildings today – results, conclusions and learnings from a cross-european demonstration programme

Speakers:
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Abstract: *"One experiment is better than a thousand expert assumptions" forms the point of departure for a cross-European demonstration programme of 6 model houses. All projects base on the active house principles and were tested 1:1 and evaluated scientifically in post occupancy evaluations. The research feedback is expressed in a comparative benchmark model developed for the purpose of qualifying theory into practice and back into theory.*

The paper presents the main common denominators among the houses and identifies distinct learnings among the many findings through excerpts from the real-life monitoring in the form of quotes, and via the methodology developed as a result of the social monitoring. The scientific reports and conclusions are the body of the empirical studies, forming a platform for discussion, definition and suggestion of common denominators; finally concluding into a recommendation catalogue of conclusions for learnings transferred to the wider housing stock, new as well as existing

Comfort, Active House, Livability

Introduction to the demonstration project programme

During 2009-2011, a demonstration project programme of 6 model homes were built in Denmark (2009), Austria (2010), Germany (2010), France (2011) and United Kingdom (2011). All houses base on the Active House principles (Alliance, 2013), Comfort, Energy and Environment (fig.1). The buildings have been tested and monitored in use, under post occupancy evaluation schemes by national research teams of engineers and / or scientists.

The approach to optimise livability whilst minimising impact is in short the aim to adapt to current requirements of modern family living, interpreted into a healthier and more comfortable life for the occupants, without a negative impact on the climate.

All buildings are designed by local planners, with one common point of departure for optimal livability through: a/ comfort levels based on natural ventilation and use of daylight; b/ be zero energy or energy positive, and c/ with a

Figure 1- project overview

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focus on the environmental impact, use of ressources and building footprint. The project programme target was set in 2008, to be responsive to the Energy Performance of Buildings Directive (EPBD), that new buildings in the EU should be `nearly zero´ energy, and basing mainly on renewable energy sources (Economy, 2013). The EPBD forms the paramount target of the programme, followed by the targets reflecting specific national targets with calculations basing on the individual country compliance tools and engines.

Sustainable indicator framework

An active house reflects on specific sustainable indicators, which are calculated in a tool and visually expressed in a radar diagram. The diagram shows the main categories, the three principles 1/ Comfort, 2/ Energy and 3/ Environment (fig. 2).

In each category there are 3 criteria, which are formed by sub criteria, e.g. 1.2 Thermal environment is reflecting summer (1.2.1.) as well as winter comfort (1.2.2). The tool enables a visual showing different scenario in one and the same diagram, thus making comparative benchmarks standing out.

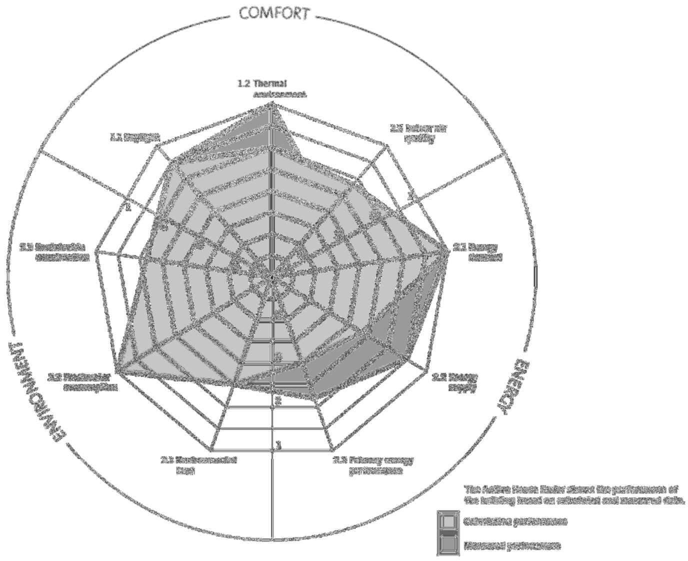

Figure 2 - Active house radar diagramme (Green Lighthouse)

The radar diagram is used as point of reference for the empirical data of this paper, in constellations with the findings from social sciences. The aim is to describe the theory of the programme, and to refer the actual performance to this, shown in one model. The active houses used as case studies in this paper are all local interpretations of a goal for optimal livability with a minimum of impact.

Reality check - real people in real houses

All the buildings have been monitored in use, on technical measures and user feedback and experience (Eleb, 2013), (Suschek-Berger & Tritthart, 2014), (Georgitsi, 2014), and via interviews for a book (Edwards & Naboni, 2013). The purpose was to check and balance the building performance, and, to gain insights on user experience, valid for qualification of future and for share of knowledge and experiences. First key learning was that there is little framework available from other demonstration projects for the sociological aspects. The sociologist team from Humboldt University were able to develop an actual scientific method, which has been applied to two of the projects (Fedkenheuer, 2013). The method works with the degree of the family´s well-being based on a three-dimensional structure of attitudes. The tripartite model distinguishes between three categories of reactions to attitudes: cognitive, affective and conative reactions, which can manifest themselves verbally and non-verbally

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and can be measured. Diary format in a digital logbook and a public blog (Oldendorf, 2012), both maintained by the family, recording their living conditions.

Approximately every 4 weeks the respondents complete an online questionnaire including both open and closed questions about the various dimensions of well-being. Every 4 to 8 weeks, more in-depth structured interviews are conducted with the parents in the form of video calls. This allows statements to be recorded in detail, and to be set into context with the respective evaluations (Fedkenheuer, 2013).
Longer structured interviews are conducted in the house at the end of each season. The team is monitoring via different investigative methods, figure 3.

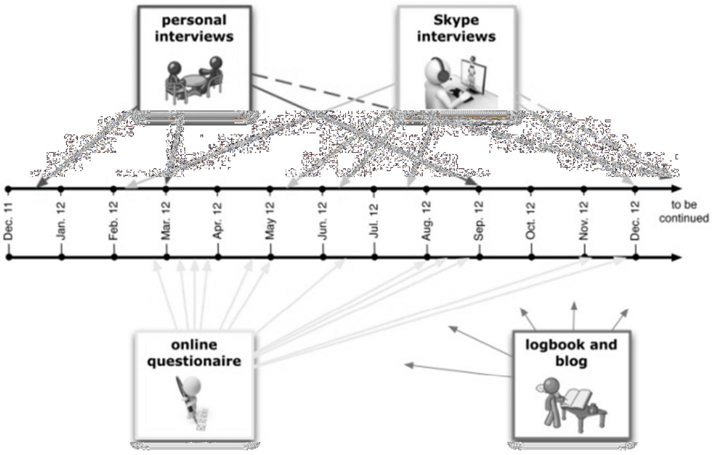

Fig. 3: Research design

Practice testing – Comfort

It can be proven that the aspects of automation as well as plenty of daylight and fresh air enhance the well-being of residents. This becomes especially evident with the project in France: some of the residents suffer from either asthma or pollen allergy and neither have had an attack or irritations. "The improvement in [his] health is a lasting one… No attacks, no Ventolin in the evening, because he had a background control therapy, but he no longer uses it. You would never believe that he was asthmatic". They attribute it to the dual-flow system of the house. Control of the air and the fact that the house appears to be so "healthy" is therefore perceived as an extremely positive quality (Eleb, 2013).

Practice testing - Energy

In order to be able to make a accurate comparison between the measured power consumption of the system equipment and the original calculations made in accordance with compliance tool submitted, a visual step-by-st ep tool has been used to follow the steps (fig 4.).

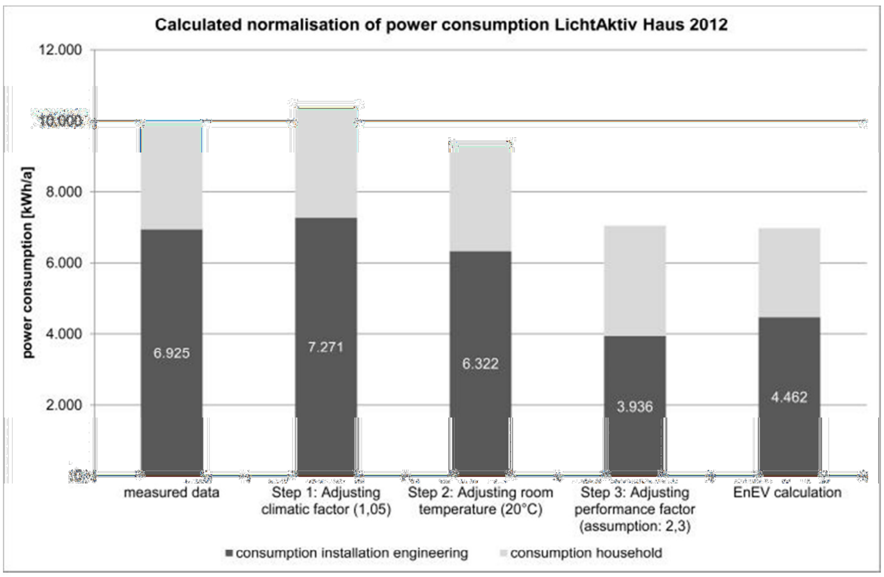

Figure 4 - step by step

The tool uses as corner references the

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measured and the designed values, and describes the steps in between, to get behind the reason for discrepancies. First step is degree days, next is difference in comfort temperature, and third step is the difference in efficiency working number of the heat pump – the coefficient of performance = COP (Wilken T., 2012).

Practice testing – Environment

The LCA calculation reflects the yearly consumtion and the different life stages of the project. The climate renovation project, LichtAktiv Haus saves the greenhouse gas emitted during its fabrication, maintenance and final disposal after 26 years of use (Hartwig, 2011)**. In arithmetical terms, the house has a neutral global warming potential at this point. The project thus confirms the assumptions that the utilisation of existing building structures and the use of sustainable raw materials in the construction have considerable advantages over new build.**

Sustainable living from a sociological perspective

From a sociological perspective the logging of environmental awareness and energy-consumption behaviour is a particularly interesting aspect of the evaluation. It was assumed that moving into the house and the interaction with it, e.g. via the consumption monitor, would lead to greater awareness in these areas and a more sustainable way of thinking. This assumption was confirmed to some extent, as occupants seem to be more aware of energy consumption in particular and it can be assumed that the house had a positive influence upon their environmental awareness. By having energy consumption and energy yield values quickly available through daily real time monitoring, and check, the occupants adopted an active consumption behaviour, parallel to the mental wellbeing of “not overspending”. So far, these behaviour patterns seem to be relatively consistent, so it is reasonable to assume that a long-term behavioural change will establish itself. The occupants' statement that they strongly identify with the sustainability aspect of the house and are proud to represent economical, sustainable living (Eleb, 2013) (Fedkenheuer, 2013).

Discussions

At a helicopter glance, the six buildings are wide apart in terms of geography, (latitude 55-48), climates (temperate, continental and oceanic), m² size (117 – 304), compactness, footprint and materials; the vernacular design approaches vary as do the cultural responses for typical middle-class family life. Nevertheless, the common denominators are distinct; generous daylight levels, from all corners of the world, as well as the principle of using fresh air to enable optimal indoor comfort. The technical features vary from use of automated natural ventilation, ventilative cooling with automated window openings, heat controls per room, CO_2 rates, humidity sensors, dynamic external solar shading, all linked to a weather station detecting the wind speed, solar radiation, etc. Detail differences within types of heat pumps, comfort levels in compliance data, u-values in the envelope, and different systems, brands, materials and system diagrammes. Common for all is that the users can override the system and take manual control of their indoor environment.

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The results of the monitoring raise key questions as for practice of national compliance engines; firstly, the typical comfort level demanded by the users is 2-3 degrees higher than standard settings in compliance engines; secondly, the typical compliance figures focus mainly on demand for heating, however in modern sustainable houses being very energy-efficient, the indoor comfort is influenced by several other aspects; thirdly, the compliance data do not include the livability aspects of thermal comfort, which are paramount to users feeling of wellbeing and motivation to live and build sustainably.

Climate renovation – the real challenge

The facts that by 2050 70% of the world's population will live in cities, and 9 out of 10 currently existing buildings in Europe will still be in use, make climate renovation the key challenge. It is particularly important that the renovation solutions presented are reproducible across Europe; if the energy demand of the EU building stock could be cut by 50% by 2020, then this action alone would deliver the major bulk of the EU 2020 target for reducing CO2 emissions by 20%.

Combining qualitative and quantitative evaluations

Often, sociological evaluations are referred to as qualitative, i.e. non-tangible outputs, whereas the technical indicators are referenced as quantitative. However, the post occupancy evaluation carried out on the test families show a ranking rather than tangibility being decisive. The PhD thesis carried out across the projects (Olesen, 2014) suggests that the an understanding of the user role would be supported through more focus on perception and sensoric experience as value-adding attributes. Theory has it, that expert planners can demonstrate errors in planning when dealing with complex systems, typically focusing on individual topics, blind for other problems, thus missing the big picture (El khouli & Drexler, 2012).

Occupant´s answers to health related issues are imperial arguments, e.g. that your child has less colds, better sleep (Georgitsi, 2014) or can avoid medication for asthma (Eleb, 2013). If we would imagine a scaling of these aspects onto societal matters as e.g. health expenses, sick days, asset management, it would be possible to swift the agenda for a sustainable transformation in the built environment.

Initially the occupants attributed their enhanced livability primarily to the modernity and size of the house, but later they regularly referred to the brightness of the living areas as a contributory factor to their increased sense of well-being. It can be discussed that it is possible to influence living preferences by positive experiences. This observation is important as the human well-being aspect is can work as motivation of mass scaling sustainable development.

Conclusions

The point of departure for the 6 demonstration projects has been to prototype experiment and test how to develop the building mass sustainably. The short of the long is that it is possible to achieve zero energy in 2020, in new built as in a climate renovation. Even in buildings built and renovated 10 years earlier. Digging deeper, 7 main conclusions can be taken forward:

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- *No conflict between low energy and high fenestration*: it is possible to achieve a good thermal performance in real use, also with high daylight levels. Good performance is achieved with automatic control of window openings and solar shading, the ventilative cooling from opening windows is particularly important.
- *Adaptation is king*: By use of the adaptive comfort principle, user comfort is programmed relative to the outdoor temperature. It is possible to avoid overheating through building design, rather than technological measures. Undercooling is accepted by occupants when they have direct influence on the between indoor temperatures and heating consumption.
- *Theory cannot stand alone*: Compliance tools results do not reflect a full picture of the degree of sustainability, energy demands and comfort levels differ vastly to theory. Environmental engineers should be aware of this factor, when programming capacity and adaptability of the systems.
- *kWh/m2/y – do not forget the /o (per occupant)*: Reviewing energy demand should also reflect footprint, i.e. assess energy demand per occupant, as space demand is also an aspect of sustainable construction. Currently the share of consumption seems relatively bigger in a smaller house than in a larger house.
- *Onsite production (also) pays off:* Good thermal comfort is possible, with solar energy produced on site. It is possible to initiate climate renovations without airbased heat recovery systems, sourcing renewable energy on site.
- *Sustainable significance of energy consumption*: Energy consumption is a detail aspect in a sustainable building, livability is the key comfort parameter.
- *Vernacular and individual*: A sustainable building can and should demonstrate cultural characteristics, giving priority to the architectural quality. The registry of sustainable tools and solutions must be instrumentalized to support planners.

Now we must diffuse and fertilize the building mass with the tested and proven solutions.

Bibliography

Alliance, A. H. (2013). *Active House - the Specifications for residential buildings, second edition.* Retrieved from activehouse.info/specifications: activehouse.info

Economy, E. C. (2013, May 4). *EPBD Recast (Directive 2010/31/EU)* . Retrieved from http://www.eceee.org/buildings/EPBD_Recast

Edwards, B. (2014). *Rough Guide to Sustainability - 4th edition.* London: RIBA Publishing.

Edwards, B. W., & Naboni, E. (2013). *Green Buildings Pay.* Oxon: Routledge.

El khouli, S., & Drexler, H. (2012). *Holistic Housing - Concepts, Design Strategies and Processes.* Munich: Edition Detail.

Eleb, M. (2013). *The Maison Air et Lumiére Experiment.* Paris-Malaquais School of Architecture: Laboratory for Architecture, Culture and Society.

ISBN: 978-84-697-1815-5

Fedkenheuer, S. W. (2013). *Residential well-being as a multi-dimensional construct. Interim report on the psycho-social monitoring of the VELUX LichtAktiv Haus during 2012.* Berlin.

Georgitsi, E. (2014). *Post Occupancy Evaluation of CLH.* London: HTA, Sustainable Futures.

Hartwig, J. (2011). *Life Cycle Assessment for the "LichtAktiv Haus" in Hamburg.*

Hegger, M., Fafflok, C., Hegger, J., & Passig, I. (2013). *AKTIVHAUS - das Grundlagenwerk.* München: Callwey Verlag.

Jastrup, M. (2012). *Sector Guide to Sustainable Buildings.* Copenhagen: Sustainia.

Oldendorf, F. (2012). *Blog*. Retrieved from www.lichaktivhaus.de

Olesen, G. G. (2014). *A Model for Enquiry of Sustainable Homes - of Model Home 2020.*

Suschek-Berger, J., & Tritthart, W. (2014). *Evaluation of the occupants experience and social quality of Sunlighthouse.* Graz: Interuniversitäres Forschungszentrum für Technik, Arbeit und Kultur.

Wilken T., R. O. (2012). *Interim report on first year in LichtAktiv Haus.* Braunschweig: Institut für Gebäude- und Solartechnik.

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Do Imported Building Environmental Assessment Methods Accelerate Culturally Appropriate Green Building Practices?

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Abstract: *Trends suggest that BREEAM and LEED® will continue to expand their global presence over the next decade. This paper presents the spatial and temporal trends in the importation of these two systems internationally in the context of cultural globalization theories to provide a better understanding of the potential positive and negative implications of such developments. The key question for this paper is now that BREEAM and LEED® have attained a global status, how will they evolve to reflect their use in a wide range of different cultural contexts. The paper concludes by exploring the possibility that we may be entering a period in which global deployed building environmental assessment "brands" will have sufficient presence and capacity, and be permitted to evolve in ways that can meaningfully accommodate national and regional cultural distinctions while still maintaining their core strengths.*

Key Words: *LEED®, BREEAM, International use, Importation, Globalisation*

Introduction

Voluntary building environmental assessment methods are still considered one of the most potent ways to transform the building industry to aspire to, and deliver buildings with higher performance. BREEAM and LEED® are two of the most mature and widely internationally recognized systems with the greatest number of assessed buildings/accredited professionals and, by virtue of their associated "brand" recognition, have the greatest presence outside their respective countries of origin. Both systems are presented by their respective owners as having a global presence and indeed such claims are also widely acknowledged. They may have, as Rivera (2009) suggests "become the forerunners in the race to become the internationally recognised sustainable building certification scheme." While many countries have developed and are using systems unique to their cultural and climate contexts, trends suggest that BREEAM and LEED® will continue to expand their global presence over the next decade. This 'importation' will occur both in countries that already have an established domestic system in place within their respective markets as well as those that do not.

Clearly there are considerable benefits associated with increased cooperation and sharing associated with the encouragement and capability building provided by these initiatives as well as the harmonising of tools and metrics. The advantages of the BREEAM and LEED® global "brands" centre on the perceived need for a common international vocabulary for building environmental assessment that can then facilitate communication between stakeholders and inter-building and inter-country comparisons. The beneficiaries include multinational companies with building/development projects worldwide and which are currently expected to adhere to numerous domestic methods and acquire green buildings to

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fulfill their corporate sustainability requirements; national and international government agencies seeking consistency in their environmental assessment of their portfolios; and building design and construction consultants who practice internationally. Moreover, advantages may accrue to large domestic companies seeking to position themselves as leaders in corporate sustainability within their local communities and strengthen their presence globally by aligning their policies and practices with current international best practices and trends, and to emerging economies trying to attract international investment by using a globally recognized "brand".

By contrast, the concerns associated with importing BREEAM or LEED®, and their inherent cultural biases and embedded practices, relate to whether such developments can support approaches to green building assessment that nurture culturally and climatically appropriate sustainable design practices within the receiving country. Rather than reinforce local practices, does the importation further homogenize built form globally and become another agent in the diminishing of local building practices and distinctiveness? Or is it that the importing process cannot anymore be defined simply in binary terms that are mutually exclusive and presented as opposite poles? Moreover, do all of their requirements, benchmarks and metrics have relevance to the majority of countries outside the United Kingdom or United States? With respect to this latter concern, to what extent can the international systems be adapted to make them meaningfully regional? Further, if the importation of the assessment methods is to be recognized to be contextual and varying from country to country due to their culturally and historically differing practices, is there a measure to describe how much the local and global aspects should be inscribed on each other to make the adaptation regionally meaningful? Such concerns are, perhaps, even more critical when shifting to neighbourhood scale environmental assessment tools.

This paper presents the spatial and temporal trends in the importation of BREEAM and LEED® internationally in the context of cultural globalization theories to provide a better understanding of the potential positive and negative implications of such developments. The paper concludes by exploring the possibility that we may be entering a period in which internationally deployed building environmental assessment "brands" will have sufficient global presence and capacity, and be permitted to evolve in ways that can meaningfully accommodate national and regional cultural distinctions while still maintaining their core structural attributes.

Exportation of BREEAM & LEED®

The importation of building environmental assessment methods is clearly linked with the ways and extent that their owners promote them abroad and offer support mechanisms for prospective users. Both BRE Global and the US Green Building Council (USGBC)/Green Building Certification Institute (GBCI), who oversee BREEAM and LEED® respectively, have declared commitment to affect positive environmental change and expand their efforts internationally. Indeed, the environmental performance assessment of buildings is now a major business, with significant revenues generated through the certification process, licensing of the systems, training and education and the accrediting of professionals. Such revenues are not solely gained through the organizations themselves but also those offering supporting services, particularly in education (exam preparation course/materials, etc). Clearly BRE Global and the USGBC/GBCI equally realise the considerable opportunity in expanding the use of their respective systems internationally during this current period of growing interest in standardisation in building environmental performance assessment.

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The USGBC have developed a set of *Global Alternative Compliance Paths* (Global ACPs) to make LEED® more accessible for projects outside of the US. These ACPS, "developed in collaboration with volunteer experts with extensive experience" in applying LEED® internationally provide "a more flexible method for projects around the world to demonstrate compliance with LEED® while maintaining the technical rigor of the rating system".[1] The USGBC are explicit in their intention to position the next version of LEED® as a "Global System" that will offer "increased technical rigor, expand market sector applicability, and strive for simplicity in usability" and to "continue to build upon the LEED 2009 Global ACPs and focus on providing global consistency for projects through integrated universal language." (USGBC, 2013) A *LEED International Roundtable* consisting of approximately thirty countries has been established that serve as "an advisory group to USGBC in advancing the relevancy and application of the LEED® rating systems internationally."[2] Collectively, these initiatives are anticipated to be more "globally aligned by including international standards and recognizing local solutions."

Spatial & Temporal Trends in Use of BREEAM & LEED® Internationally
As of September 2012, BREEAM was being used in a total of 23 countries (including the UK), with 2,888 projects listed on the *GreenBookLive Database* covering the period from 2008-2012). From these, 671 were projects located outside the UK, constituting a 23% of the total number of projects pursuing certification in the world. The LEED® rating system was used in a total of 135 countries excluding the US with a total of 47,661 projects. From these, 6,358 are projects located outside the US, constituting a 13% of the total number of projects pursuing LEED® certification around the world. Moreover, there were 483 BREEAM Accredited Professionals and 165,918 LEED® Accredited Professionals around the world. Broadly speaking, in terms of assessed buildings, BREEAM's international presence is primarily in Europe whereas LEED® has a wider geographic distribution of projects. While the numbers of registered and assesed buildings have grown since 2012, the trends described above can be assumed to remain the same. Cole and Valdebenito (2013)

The willingness of the importing country to accept and cooperate in the dissemination of assessment methods is also critical. Clearly, BREEAM or LEED® building environmental systems are imported as the result of someone's decision to do so – and there a many different forms that this can take as well as reasons for doing so. Cole and Valdebenito (2013) illustrate that a significant distinction in the use of international systems lies between developing economies and developed economies. Many developing countries do not have a domestic system in place and building owners have their building assessed only by LEED® and some, which also do not have a system in place, "imports" several systems – LEED®, BREEAM, DGNB and SB Tool. These trends may be the result of their location and the influence of the different system being used within the region where they sit, familiarity with and accessibility of different systems, or the influential role of the Green Building Councils (GBCs) that may either encourage the use of a domestic system or support a broader range.

Multi-national companies who have building/development projects worldwide may favour the use of one of the major "international" systems. In both developed and developing economies, multinational projects are typically the first to achieve final certification using LEED® or BREEAM. As such, it is reasonable to argue that international developers and multinationals

[1] LEED is Global, http://www.usgbc.org/DisplayPage.aspx?CMSPageID=2628
[2] http://new.usgbc.org/about/committees/international

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have played a significant role in driving green building performance assessment. In developing economies, however, although multinationals were the first projects to be registered and to obtain LEED® certification, over time the number of registered domestic projects has greatly exceeded the number of multinational projects. This may suggest that emerging economies are trying to attract international investment by using a globally recognized brand as LEED®. Also, some of the larger domestic companies may be seeking to position themselves as leaders in corporate sustainability within the local community and thereby align their policies, practices and accommodation with current international best practices and trends.

One of the most significant developments regarding the organizational context for building environmental assessment methods is the increase in the number of Green Building Councils, their linkage through the *World Green Building Council* (WorldGBC) and their sharing experiences with using assessment methods. Two key aspirations within the World GBC's mission are to ensure Green Building Councils are successful and have the tools necessary to advance and to support effective green building rating systems. Clearly there are considerable benefits associated with increased cooperation and sharing associated with the encouragement and capability building provided by these initiatives as well as the harmonising of tools and metrics. The presence of a GBC clearly has an influence on the uptake of green building certification and market transformation in their respective countries.

Other forms of communication and exchange clearly influence awareness of various assessment tools. A small survey (N=26) carried out mid-2010, Larsson and Woodman (2011) to understand the issues associated with using building environmental performance rating systems outside of their country of origin, indicates that in every instance that a particular system was imported because "it was well known through media or other public sources, LEED® was the imported system in use." Moreover, there were no reported cases where the "value of management and training support provided by the exporting organisation, or marketing efforts of imported consultants was selected as a reason for use of the imported systems." (p. 4)

Globalisation of Assessment Methods – In Search for Dynamic Balance

Cole and Valdebenito (2013) present the complex and varied set of ways that the two major environmental assessment methods – BREEAM and LEED® – are being used beyond their countries of origin. And, given the rate at which developments are unfolding, the implications of their widespread use on global green building performance remains unclear. Within this unfolding future, perhaps the larger issue of concern is the ability to retain or nurture approaches to green building assessment that support culturally and climatically appropriate design practices within an emerging context of globally deployed "brand" systems. Indeed, the key question for this paper is now that BREEAM and LEED® have attained a global status, will they evolve to reflect their use in a wide range of different cultural contexts and, if so, in what ways?

Both developed and developing countries are currently wrestling with how to live in a resource-constrained world and a return to local living, rethinking the relationship between humans and nature and how building development can maintain or reintroduce natural systems to create a harmonious coexistence between them and emphasising food consumption and waste management within cities and seeking new building typologies for production and

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recycling, particularly in high-density areas. Emerging approaches increasingly emphasize the importance to dynamically appropriate the newest globally accepted practices to the local context, rather than segregating one from another. Both profesional and student entries to the Singapore-based FuturArc Prize competition, for example, through their design propositions consistently aspire to repair past damage and restore capabilities that have been lost—social, cultural and ecological . As the entrants come from different countries in Asia, the entries embody a rich and complex mix of cultures, philosophies, technological sophistication, capabilities, and wealth. (Cole, 2014) Many of the submissions draw on and interpret these regional and cultural references—vernacular building, landscapes, costumes, etc. This desire to reengage cultural heritage and place has been accompanied by an array of renewable energy technologies, onsite rainwater harvesting, and wastewater treatment technologies. What is equally evident, and perhaps more significant, is the attempt to consider these as integrated systems and to express them in a way to nurture an environmental ethic within the communities that the projects are situated. Such emphases are qualitatively different from the ideas and aspirations current evident in, or supported, by the major building environmental assessment methods and not easily accommodated within them.

One could anticipate that a restoration of regionally based architectural responses will not necessarily emerge from a nostalgic reflection on primitive and vernacular forms, but a thoughtful response to climatic, resource and environmental constraints of place, drawing on the appropriate use of contemporary technological capability. The understanding of technology is no longer limited to the two prevailing binary conceptions of technology as described by Ihde (2008) – "the utopian views that technology is capable to solve humanities problems of any kinds and the dystopian views that technology is having potentially negative long-term consequences" –both of "which tend to be rooted in misunderstandings of the complexities" (Riis, 2008) such as "technology's concrete specificity, variability, context dependency, tendency to defy prediction, historical and cultural 'embeddedness'" (Rosenberger, 2010). It is therefore evident that new and advanced methodologies cannot be simply defined as separate category independent from the context, because such methodologies both influence the cultural context they are applied to and consequently change according to the expectations prevalent in that cultural context. Given the increased deployment of building environmental assessment methods within developing countries, the ways and extent that local context is embedded within them would seem critical.

Significant alteration to local practices were initiated in the late-nineteenth century with the importation of western expertise and hence building materials, objectives and styles in the modernization programs of many countries world-wide. The most profound changes perhaps occurred in the 20th century with the emergence and large-scale dissemination of the Modern Movement, first among an architectural elite in the 1920s and then more comprehensively in the post WWII era as modern architecture was embraced by governments and corporate interests. The Modern Movement had decreed its tenets international in scope but with its adoption, the materials, forms and technologies of its original formulation in Western Europe and America were also endorsed. Coupled with increased mobility, communication and awareness, few parts of the world were immune to the powerful homogenizing of architectural form. Now, of course, the mechanisms and capability to diseminate information and experiences is far greater and presumably having consequence for the both promoting and importing "brand-name" assessment methods. But does the globalization of the "brand" building environmental assessment methods produce homogeneity and a loss of diversity of regional building practices? And will the value-laden standards, performance expectations, strategies and requirements embedded within these

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methods create the same homogeneity in green buildings globally that the Modern Movement initiated during last century and now evidenced in all cities worldwide?

Many societies are also struggling with the process of negotiation on how to find the appropriate combination of maintaining or reviving local building traditions and along with achieving the benefits of being seen to operate within global market. Such an idea is equally relevant in reconciling the regionally-specific relevance and global applicability in building environmental assessment tools. Robertson (1992, 1995) uses the notion of "glocalization" - characterized by the "interpenetration between local and global rather than a situation of local being overridden with global." Robertson further suggests that both local and global scales of engagement have the potency and power to both "inform and construct each other", and characterises the local-global encounter as both the "universalization of particularism" and "the particularization of universalism". This argument, *Koç (*2006) suggests, "leads to the idea that whereas globalization transforms the local identities, customs and values, inhabitants are also able to transform the global into their local establishments, suggesting that new identities not necessarily belonging to either local or global may be constructed." This emphasis – addressing regional priorities and operating globally – if defining charactistics of building environmental assessment methods would, as Hoogvelt (1997) states, represent a "a kind of superior cultural intelligence owing to the advantage of in-betweeness, the straddling of two cultures and the consequent ability to negotiate the difference" (p. 158). That a fully matured global information system and culture may instigate and permit the restoration of regionally based practices is central to this notion of "glocal". Derived from global and local, "glocal" recognises the need to recognise the constantly changing and evolving balance between "the invisible global forces" and the "actual sense of place and culture." (Nagashima, 1999)

Almost three decades ago, Buchanan (1984) suggested that "[p]erhaps (and hopefully) what we are witnessing is the traumatic period prior to the birth of a viable global civilisation in which networks of communication and trade will no longer be homogenising and destructive agents but will have such abundant capacity as to allow regional peculiarities to survive and be savoured." The pervasiveness and overwhelming momentum of information and communication technologies now dominate industry, commerce and recreation and, as such, dictate the pace of almost all human activity and expectation. We are an increasingly connected species and are entering, what Buchanan suggests, a "truly universal civilization" that "will not only envelop the world and give its citizens the breadth of experience so ordered" but will "also encourage that depth of experience that comes from being rooted in, and caring for, local issues and which is another dimension to the idea of being universal." The emergence of approaches supporting greater local authority (e.g., "localism"), local food production, etc., would seem to imply that Buchanan's proposition is unfolding in tangible ways. The main proposition of this paper is that a similar process will occur with respect to the global presence of BREAM and LEED environmental assessment methods, and capacities of their respective owners, permitting, accommodating and supporting local and regional practices.

Conclusion

The importation and exportation of international "brand" building environmental assessment methods – BREEAM and LEED® – are likely to continue to increase for the foresable future. In the same way that they have evolved domestically in response to improved understanding of environmental issues and priorities together with practical considerations such as reducing the time, effort and cost in performing the assessments, this paper has proposed that are also likely to evolve in ways that respond to the different cultural contexts in which they will be deployed. Such an outcome will depend on the BRE Global and the USGBC/GBCI continuing to develop mechanisms that permit appropriate regional adaption, which recognize the complex dynamic relationship between the imported system and local context, and enhance the dynamic balanced integration of the two rather than forecefully inscribe the new methods. If this proves to be the case, it will negate much of the current apprehension regarding homogenising effects of importing of the “brand-name” methods.

References

Buchanan, P. (1984) Only connect: the need for regionalist architecture. *The Architectural Review*, 176 (1052), 23–25.

BRE Global (2009) BREEAM – The Environmental System for Buildings Around the World.

BRE Global, (2013) http://www.bre.co.uk/page.jsp?id=1763 Downloaded January 20th 2013

Cole, R.J., FuturArc Prize: Building New Capabilities, *FuturArc*, Singapore (in Press)

Cole, R.J., and Valdebenito, M.J., (2013) The importation of building environmental certification systems: international usages of BREEAM and LEED, *Journal of Building Research & Information,* 41(6) 662-676

Ihde, D., (2008) *Ironic Technics*. Copenhagen: Automatic Press.

Nagashima, K., Glocal Approach Toward Architecture of the Future, Union of International Architects Work Program, Architecture of the Future.

Riis, S., (2008). *Review essay: Postphenomenology: 'Festschrift' for Don Ihde (Underconsideration: Evan Selinger'sPostphenomenology: A Critical Companion to Ihde).* Philosophy & Social Criticism 34:449. DOI: 10.1177/0191453708088513Rivera, A., (2009) International Applications of Building Certification Methods: A Comparison of BREEAM and LEED. *Proceedings PLEA2009 - 26th Conference on Passive and Low Energy Architecture*, Quebec City, Canada, 22-24 June 2009

Robertson, R. (1991). *Japan and the USA: The interpretation of national identities and the debate about orientalism.* IN: Abercombie, N., *et al.* (Eds.), *Dominant Ideologies*, London: Unwin Hyman.

Robertson, R. (1992). *Globalization: Social theory and global culture*. London: Sage Publications.

Rosenberger, R., (2010). *Deflating the overblown accounts of technology: a review of Don Ihde`s Ironic Technics*. AI & Society 25:133-136. DOI 10.1007/s00146-009-0222-5

Larsson, N., and Woodman, W. (2011) *Survey on use of domestic and imported building environmental assessment methods*, International Initiative for a Sustainable Built Environment (iiSBE) report, 19 August, 2011

Koç, M., (2006) Cultural Identity Crisis in the Age of Globalisation and Technology. *The Turkish Online Journal of Educational Technology – TOJET* January 2006 ISSN: 1303-6521 5(1) Article 5 42

USGBC (2012) LEED International,
http://www.usgbc.org/DisplayPage.aspx?CMSPageID=2346 Access July 24th 2012

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Session 34:

How can traditional architecture contribute to sustainability? (II)

Chairperson:

Laureano, Pietro
President of International Traditional Knowledge Istitute (ITKI) IPOGEA

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Earthen architecture & sustainable building: Proposed union between authenticity and technical renovation - Case of south moroccan villages -

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Abstract Summary:

In this paper, the two-edged nature of earthen architecture is explored: Its Styles' Authenticity and its Sustainable Nature. In the southern area of Morocco as well as in several villages in the world, such kind of traditional buildings reflect the image of the ontological "truth" of some nations' architecture in need of salvation. In addition, those earthen buildings possess a high environmental quality which we would promote. Testing the validity of the hypothesis goes through two stages: The first stage is to explain the aspects of authenticity in the lifestyle generated by that architectural style; the second stage describes the characteristics of the materials that respect pertinently the environment. The purpose is to promote a sustainable re-creation of an architectural heritage that is basically sensitive to the environment.

Keywords: Earthen Architecture; Sustainable Traditionnal Building; Re-creation of Identity; Re-creation of Earthen Technicality.

1. Introduction:

Earthen material is one of the most common elements of the planet, the most available, the most inexhaustible, the most versatile, the least expensive, and the least harmful to the environment. This material builds, at least partially, the houses of more than a third of the World inhabitants. Twenty per cent of these area's homes are representing the UNESCO cultural sites and are mentioned in the world's heritage list. **[1]**

In today's world, such earthen constructions are the first to be razed and replaced by a generalized type that neither respects the diversity of cultures nor the originality of the material. The tendency to opt for modern sustainable architecture often overlooks the validity of earthen methods despite their several environmental qualities.

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In the same context and between 1900 and 1989, the Egyptian architect Hassan FATHY has actively introduced the concept of "to build for oneself". He especially encouraged poor Egyptian families to develop construction techniques from earth in order to keep the authenticity of their villages. In addition, he has revived this construction through the implementation of new projects fully built from earth. **[2]**

In Morocco, many international attempts were engaged to save earthen structures in some distant villages **[3]**. These attempts have aimed to restore this heritage, while the real need for us is the re - adaptation of earthen architecture as a building system which is worthful. Then the biggest challenge in this research is to find how can we dually protect the architectural patrimony and build sustainably? How can we make use of new tools to construct buildings of ancient style? How is it possible to adapt “earthen architecture” to be fairly sustainable? And how can we take advantage of traditional architecture to make similar buildings that are actually authentic and durable enough?

Analyzing the double value of earthen architecture in a specific context -which is Moroccan community-, will link two important topics that are rarely connected by researchers: the earthen architecture’s role in preserving the community’s identity and the technical ingenuity of the earth as a sustainable building material.

2. Methodology

2.1. method and tools:

This research adopts a set of analytical tools conducive to the study objectives. The research method is divided into two main components:

a - Analysis of the ideological component:
- Understanding the architectural concept of the mud house in Morocco (Life-style);
- Explaining authenticity foundations of the community;
- Identifying problems related to ideology in the modern context;
- Reviewing the functional and formal image of earth houses.

b - Analysis of the technical component:
- Understanding the architectural concept of the mud house in Morocco (HQE);
- Understanding traditional earth construction techniques;
- Identifying the technical problems of the earth material as a sustainable option;
- Reviewing the appropriateness of the earth as building material in sustainable scenario.

2.2. Scope and limitation:

To delineate areas of analytical intervention and to focus on the main points of this research, all theoretical (a) and technical (b) components of earthen architecture were sorted. The analysis focuses predominantly on the most significant aspects of our topic. ***(Figure1)***

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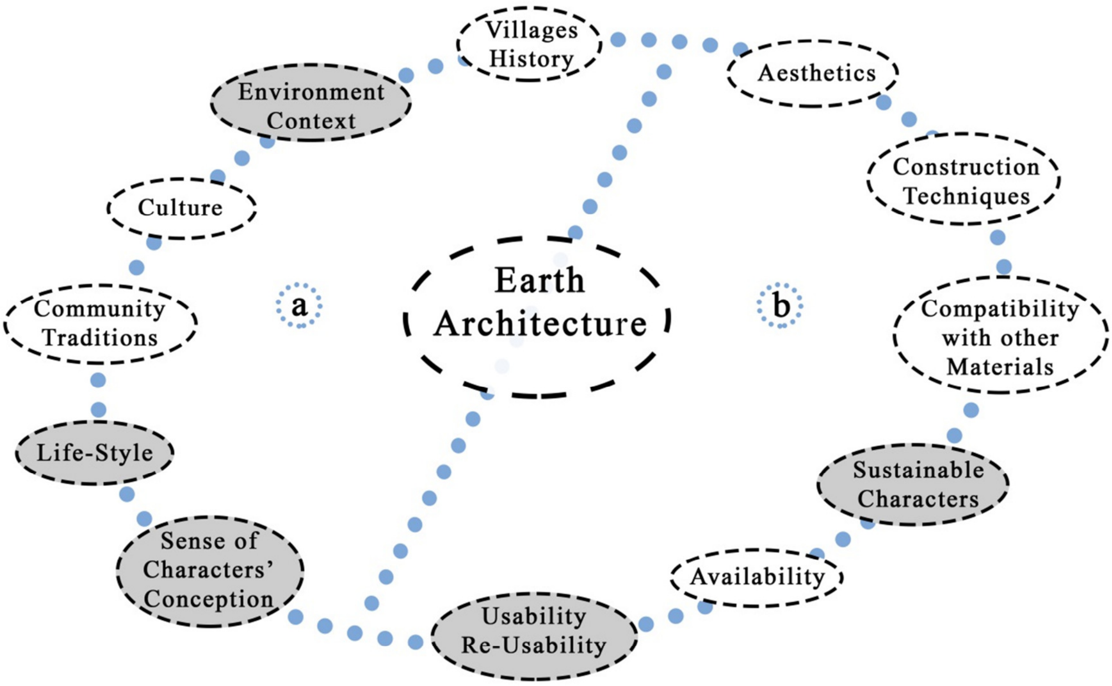

Figure 1: *Sorting of theoretical (a) and technical (b) components of earth architecture, and selection of main aspects for the topic (grey areas).*

3. Results and Discussion

3.1. Ideology and Authenticity :

Moroccan earth villages have been initially built by the communities that have been settled since many decades in large buildings as a "Qsser" (earthen compound enclosing houses of one big family and their servants). The choice of the location is based mainly on the water criterion ***(Figure2)***. Thus, we find that most of these villages are settled in a given oasis near valleys. Consequently, these conditions promote accessibility to a good earth material to build their homes. In addition to water, we quickly feel a sense of orientation to the prevailing winds as compared to large set of blocks that respects the opposing fronts and offers each habitat unit a clear view to the landscape. The second criterion for this choice was to insure security against attacks from enemies and thieves at that time. Thus villages were located in high positions in order to keep an overview of all directions. (***Figure 3)***

The environmental context of these villages is in perfect harmony with the landscape. It has a very strong concept of "living in earth" which is environmentally better than any other modern methods of construction. In this way, earthen architecture validates already the eco-construction target of the sustainable architecture (HQE).

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Figure 2: *Personal Photo, oasis and valley of Douar Tamnouguelt, Ouarzazat, Morocco.*

Figure 3: *Personal Photo, Qsser Aït Benhaddou, Ouarzazat, Morocco.*

The location of these villages mentioned above is also in accordance with the mentality, culture, traditions and primarily with the religion that is Islam. This belief has always been a faith and a code of life: something that guides a specific life-style that we can easily read outside and inside houses. The founding principles (constants) of earthen architecture in Morocco were basically derived from Islamic concepts:

- Privacy / Modesty: Narrow streets that enhance the private space as well as a sleek exterior with the principle of an inward opening on central patios which represent “the outside into the inside”. ***(Figure 4) and (Figure 5)***

- Union / Centrality: All houses are built one next to another in gathering spaces with a minimum of space connection and next to central points that represent functional landmarks like the mosque or the well.

- Spontaneity / Respect: Basically, the village traces only its limits and boundaries, while all residential units multiply spontaneously according to community rules and within a total neighborhood respect.

The authenticity of this architecture remains in perfect harmony between a belief (based on the principles of unity and modesty) and urban- architectural practices (that accurately reflect the ideological needs of the people). As such, it is a real sustainability in terms of architectural style as well as of community life.

The non-consideration of authenticity influences directly people attitudes (Space makes Human as well as Human makes Space). Commonly perceived as only a vernacular form of architecture, earthen construction has seen increasing standardization andindustrialization in recent decades. Consequently that current modernization overlooks the meaning of concepts and causes many mutations in the "Muslim" space; the technicality takes priority and modern manufacturers do insert the same blocks with the same materials and the same designs in the whole world. It is an act of killing the multi-diversity; an act of killing the inherited “sustainable”.

Figure 4: Personal sketch, back street in Douar Tamnouguelt, Ouarzazat, Morocco.

Figure 5: Personal sketch, chicane entrance of a house, Douar Tamnouguelt, Ouarzazat, Morocco.

3.2.Technical characters and Sustainability:

Significant efforts have been made over last years in developing earthen architecture through preservation measures. This progress could be inter- linked in many ways to the approach of reintroducing earthen construction as a sustainable building; the continuity of the tradition of building with earth facilitates conservation practice and legacy, while promoting this important architectural technicality inspires its future use.

Indeed, the demonstration of the qualities of earthen architecture in the view of the "HQE" is quite possible. Technically and concerning the urban plan, the compactness of earthen village houses has ideally the requirement of reducing Form Factor (CF) (or shape coefficient) which is one of the foundations of an effective eco-design, and which is necessary for reducing the heat losses in the building. Then, there is a central open patio that acts as a skylight, as a thermal regulator, and which also ensures great ventilation for all interior spaces. **[4]***

In addition to the design quality of this style of architecture, mud walls grant soundproofing, struggle against heat losses and provides great inertia that absorbs peak temperature, then, stabilizes ambiances and gives real comfort even in bad climatic site conditions.

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This 100% recyclable material is a renewable resource with a big potential to be reused without limits. Likewise, the earth is therapeutic, because it treats infections of the skin and kills bacteria and mites. In addition, it is worth mentioning that an earthen construction uses only 3 % of the energy used in modern construction. In all its forms, it has no direct role in water consumption during the life-cycle of the building, as it has no unhealthy nuisance on work site. Recent research has also shown that it can be mixed with several new materials likely to improve and resolve its probable defects (such as low resistance to rain, earthquake, and thermal bridges).

Very quickly, we realize that the problem of thermal bridges - which is a general problem - can easily be treated for a low cost. Similarly, resistance to rain can be achieved through additives or via a periodical maintenance done by the inhabitants themselves. As to earthquakes (that is not a particular issue in Morocco), studies show the opposite: The earth material alone, is not an excellent material against great earthquakes because it is not a high pressure resistant material. It has however many high mechanical properties such as a certain deformability under compressive stress and shear. Consequently, earth becomes an interesting earthquake material. Practically, if we want to build in the ground in seismic regions, it is possible to combine it with another material resistant to tension like wood. **[5]**

Timidly supported to face the global economic challenges, the earth material with its various forms and techniques is an excellent sustainable material that respects the environment and provides a strong aesthetic that is fading out bit by bit.

Figure 6: *Personal Photo, façade of a private house, Ouarzazat, Morocco.*

Figure 7: *Personal Photo, traditional ceiling, private house, Ouarzazat, Morocco.*

4. Conclusion

"*Governmental authorities frequently consider earthen construction to be substandard, even though it may meet the housing needs of the population more appropriately than other building materials and techniques*." **[6]**

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Nevertheless, adaptation and improvement of the earthen building is simultaneously a double action which consists of “building with the local populace” and “building for oneself”. This approach will show the degree to which some traditional cultures are historically sensitive to the environment and particularly technically ingenious in spite of the simplistic building’s tools in their possession. Ideologically deep and encrypted via social codes, this earthen cultural tradition of ‘living’ and ‘building’ gives “green standards” a new dimension.

5. References

[1] L'architecture de terre: pour un patrimoine matériel et immatériel respectueux de l'environnement.// © UNESCO 2009 – 2014

http://www.unesco.org/new/fr/unesco/resources/earthen-architecture-the-environmentally-friendly-building-blocks-of-tangible-and-intangible-heritage/

[2] Hassan FATHY. 1973, architecture for the poor. An Experiment in Rural Egypt. //University of Chicago. p: 336

[3] Alejandro alva balderrama. January 2011. Earthen Architecture Initiative. // the getty conservation institute. //newsletter 16.1.
http://www.getty.edu/conservation/our_projects/field_projects/earthen/

[4] Fabio VARONE. Architecte D.F.A.U.N. Session 2008 / 2009..Mémoire Formation Longue HQE.. // E.N.S.A.L. pp. 06-07.
http://www.lyon.archi.fr/sitehqe/site_carnetdevoyage_2004/carnetdevoyage/HQE_M%E9moires/QEB_memoires_2008/varone.pdf
* Shape Coefficient (SC or Cf = Coefficient de Forme) = Ratio between the exterior area of the envelope and the volume of space whom it contains.

[5] Réseau Ecobatir, Groupe Terre. 4 février 2004.Construction en Terre et tremblements de terre.
http://www.passerelleco.info/article.php?id_article=263

[6] Alejandro alva balderrama. spring 2001. The conservation of earthen architecture, the getty conservation institute. //newsletter 16.1.
Http://www.getty.edu/conservation/publications_resources/newsletters/16_1/feature.html

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Development of a Self-Compacted Clay based Concrete, rheological, mechanical and environmental investigations

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Abstract: *Without transport needs and infinite recycling possibilities, earth is one of the building materials with the lowest environmental impact, but its development is hindered by construction time with conventional earth construction technique. The objective of this study is to use all the recent cement and concrete technologies in order to improve earth materials by providing a material that is as easy and as cheap to use as current concrete products: a Self-Compacting Clay based Concrete (SCCC). This technology transfer can be done as both materials have analogies in terms of physics. Rheological and mechanical measurements performed in earth materials containing polymers and a cementitious binder show that it is possible to obtain a new earth material enough fluid to be poured in a formwork and getting a sufficient strength to be demolded at early age. Furthermore, we show that its carbon footprint is competitive compared to the concrete block.*

Keywords: earth, concrete, clay, environmental impact

Introduction

Traces of earthen architecture date back from 10’000 years ago and it still used in most climates and societies *[1]*. Without transport and with infinite recycling possibilities, earth is one of the building materials with the lowest environmental impact *[2, 3]* followed by a very efficient temperature and moisture regulation of indoor living spaces *[4]*. We can currently observe a strong development of earth construction, probably due to environmental concern. However, this development is limited due to conventional earth construction technique very time and cost consuming. On the other hand, we have cement, which is an incredibly easy to use material but that has a significant environmental impact *[5]*. In the latter material, a lot of engineering and science has been invested in order to improve the understanding and the processing of cement based concrete whilst in the case of earth no or very little engineering improvement has been made.

The objective of this study was then to transform earthen architecture by providing a material that is as easy and as cheap to use as current concrete products, by using all recent and concrete new technologies. This technology transfer can be done as cement and clays have a lot of analogies in terms of colloidal interactions and adhesion forces, even if the cohesion forces between particles are much weaker for clay particles *[6]*, due to the difference of consitute binder (no hydraulic reaction occurs). To improve the material workability and mechanical properties, a careful control of the rheology of the clays requires a better understanding of colloidal interaction between particles *[7]* and knowledge transfer from the fundamental physics of grain and colloidal to the civil engineering *[8]*. In this way, recent attempts have been made to fluidify earth material in order to be able to cast it with the same techniques as concrete. The French laboratory CRATerre and the University of Mokpo *[9]*

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have experimented castable earth where cement plasticizers are used to reduce the yield stress and around 8 to 10 wt% of cement is used to allow the setting (sufficient strength in order to remove the formwork). It works but the understanding of the exact behaviour of clays is not understood and too much cement is still used. Alternative cementitious binders, such as Calcium Sulfo Aluminate cement (CSA), can thus be used instead of cement in order to have a reduced environmental impact and overcome difficulties of high pH and high Calcium content of Ordinary Portland Cement (OPC) when introduced in a clay based matrix. Furthermore, as unique binder in earth, clay, an inorganic charged particle, can have its surface interaction changed with the help of organic plasticizer as cement particle has, in order to have a flowable paste. The deflocculation can be reached using this type of admixtures. The difficulty is then to be able to modify their behaviour after the clay based concrete has been casted, in order to remove the formwork.

In this paper, we study the behaviour of earth materials with and without CSA at fresh and hardened state. We highlight the ability of cement plasticizer to deflocculate clay particles, effect enhanced by the presence of CSA. It is shown that this alternative binder, besides improving earth material fluidity, allows providing to the material a sufficient compressive strength at early age. At the hardened state, the material provides sufficient strength to be used as a structural building material for low rise housing (up to 2 storeys).

Materials and procedures

Materials: A commercially available earth for plastering was used in this study. It contains 55% of fine particles (< 100 µm) (Fig. 1), including clays and silt. The high range water reducing agent (HRWRA) was a polycarboxylate ethers (PCE) type polymer from cement industry, Viscocrete 3082 (Sika©). In order to estimate the effect of the HRWRA on earth material deflocculation, various amount of PCE were added to the mix (0.5%, 1% and 2%). As in concrete, the water to clay ratio plays a major role. In this study, this ratio was kept low (0.35) to obtain an initial material sufficiently thick, with low porosity and to be able to evaluate the efficiency of admixtures. Furthermore, the impact of CSA, an alternative cementitious binder, from Buzzi Unicem© is studied. This choice is motivated by its lowest environmental impact compare to OPC.

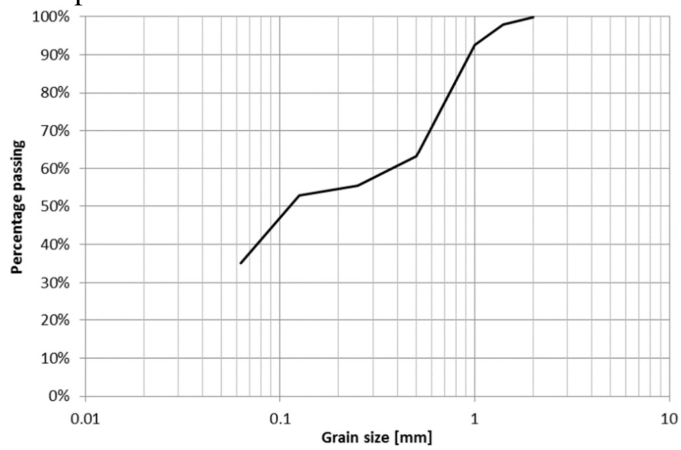

Figure 1: Particle size distribution of the studied earth material

Procedures

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Rheological characterization: The rheological behaviour was measured using slump flow test. Directly after mixing, a cylindric mold was filled with the mix and lifted. By measuring the diameter of the sample after flow stop, it is then possible to convert spread into material yield stress thanks to analytic solutions *[10, 11]*.

Setting and hardened properties: In parallel of rheological characterization, setting properties at early age of mix designed materials were tested thanks to a penetrometer, measuring setting over time by sampling a specimen at different location and time *[12]*. Other mix samples were poured into standard molds (4x4x16) in order to evaluate their mechanical performances. Compression and flexural tests were performed at 24h (just after demolding), 7 and 28 days.

Results and Discussions

Fresh properties of earth based concrete: in order to envisage the feasibility of the process for such material, it is necessary to study its behaviour at fresh state. It can be seen in Figure 2a that the use of PCE with earth reduces its yield stress but is much less efficient than when CSA is introduced into the mix. Indeed, 5% of CSA decreases drastically the yield stress in presence of PCE. This result can be explained by the effect of Ca^{2+} and high pH content in solution that allow adhesion between negative charged surfaces (DLVO theory). Indeed, as we can see in Figure 2a, an increase of PCE amount decreases the yield stress of earth material due to the adsorption of polymer (negatively charged) at the surface of clays particles involving an electrostatic repulsion and provides steric hindrance that prevent close contact between particles, reducing the magnitude of the attractive forces *[13]*. It seems that a lower amount of CSA could allow an optimal efficiency and a dosage of 1% of PCE is sufficient to reach the optimal rheology. This experiment shows that it is possible to use PCE from cement industry to deflocculate clay particles (decrease in yield stress) as soon as a small amount of cement is present, allowing to produce a earth concrete which can be poured into a formwork.

Setting properties of earth based concrete: concerning setting, increasing water content allows for an increase in the initial workability, but will induce a larger shrinkage at the hardened state. Therefore, it seems fundamental to be able to work with a clay mixture that has the lowest water content in the fresh state (but still flows) and to remove this water once the material is placed in the formwork in order to be able to demold it at early age. We tried to remove water by transforming this liquid water into solid through a hydraulic reaction. This strategy, studied by penetrometer measurements, is encouraging as showed in Figure 2b, where early compressive strength is plotted as a function of time. Thanks to this methodology, we can clearly follow the early stage of the setting of the various tested materials: earth mixture with and without CSA. The choice of this type of cement, besides its lower environmental impact, was justified by the fact that the reaction products from CSA consume much more water molecules than the one involved in OPC (10 to 30 *vs* 5 to 8). It is therefore proposed that the cement setting will allow to chemically bind the water used to allow earth to flow in its fresh state. Indeed, during the hydration of CSA, ettringite is formed in the accelerated phase and act as a “sponge” by pumping water *[14]* resulting of an increase in early compressive strength. In Figure 2b, we can clearly observe that, without the addition of

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CSA, no change in compressive strength occured. Furthermore, a material must display a minimum compressive strength of the order to 1 MPa at 24h to be able to be demolded. This result shows that it would not be possible to remove the formwork of clay based concrete if only PCE was used. By the addition of 5% of CSA in the earth mixture, a compressive strength of 1 MPa is reached during the first hours (~5h), and the demolding is made possible. At lower content (2.5% of CSA), the same phenomenon occurs but with a reduced amplitude. A maximum potential is reached after 10 hours at 0.4 MPa. It has to be noted that these final strengths could be higher if the initial water content would have been reduced.

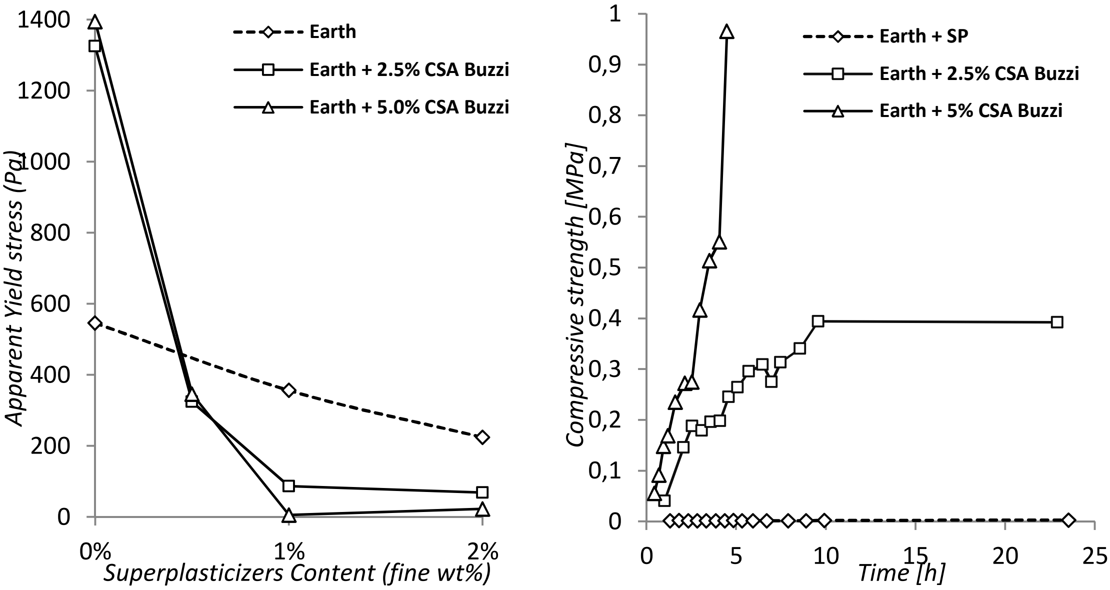

Figure 2: a) effect of SP and CSA cement on earth with 55% of fine particles and b) early development of compressive strength over time measured by penetrometer

Hardened state of earth based concrete: all these experiments have been performed with a low water to fine ratio (W/F=0.35). However, the compressive strength of the earth concrete can be increased when the water content of the paste is reduced (Fig. 3).

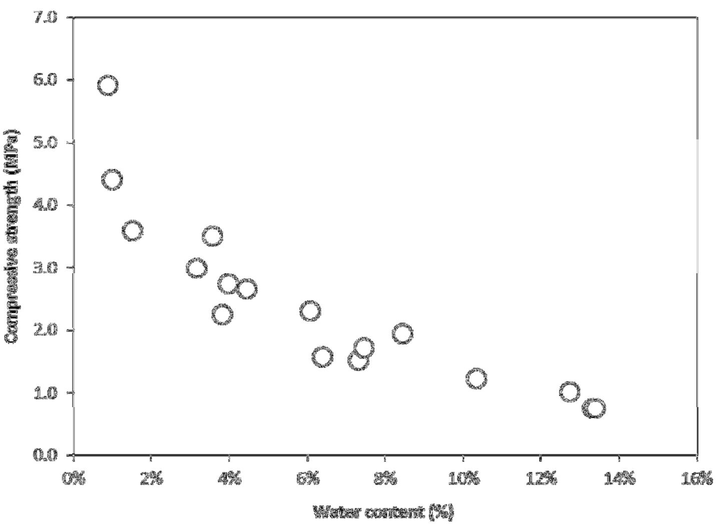

Figure 3: Compressive strength as a function of water content in sample. (5% CSA and 1% PCE)

Indeed, compressive strength of earth material is known to vary with the dry density and the clay content for compressed earth block *[2]*. By reducing the water to binder ratio, the porosity and permeability of the material decrease, leading to a higher compressive strength. We can show here that the same results can be achieved with a material poured in a formwork, rather than compacted. It is not surprising as it follows the physic of grains that has been successfully applied to concrete *[15]*. It can also be noted that once the formwork is removed, the clay based material can dry which increases its mechanical performance (Fig. 3).

The material that we have prepared has a final compressive strength of 1 to 6 MPa, and as cement was used in order to chemically remove water from the mix and not to provide a higher strength to the material we do not expect to have a much higher strength even when mix design will be optimized (reduced water content, better granular optimization and density packing). 5 to 8 MPa is therefore the target strength that we will be able to reach for the SCCC.

Environmental performance of the new earth based concrete: the material developed in this study has a much lower strength than a conventional concrete, and can therefore not be compared to it. However, the strength is similar to concrete blocks and potential applications in terms of construction cost for two storey buildings would be similar. Data on efficient production process for concrete block technologies show that the CO_2 emissions related to the production is around 15 kg $CO_{2\ eq.}$ per m^2 of wall *[16]*. For the future SCCC developed with the studied technology, one can consider that we will add coarse aggregates to the mortar in order to have 50% of paste and 50% of aggregates. The mix design and their relative carbon footprint are shown in table 1 for SCCC and concrete block. Data for environmental impacts of components have been taken from Ecoinvent v2.

Table 1: Mass and CO_2 emissions associated with the production of $1m^2$ of wall with a concrete block technology and SCCC.

	Functional unit = $1m^2$ wall			
	Concrete block technology		Self compacted Clay concrete	
	Mass kg	Environment kg $CO_{2\ eq.}$	Mass kg	Environment kg $CO_{2\ eq.}$
Cement	20.8	14.6	9	5.0
Chemical admixture	0.4	0.3	11	7.7
Earth mortar			323	1.0
Aggregates (sand & gravel)	196.6	0.6	230	0.7
Water	10.8	0.0	65	0.0
Total environmental impact		**15.45**		**14.5**

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It is interesting to see that first both products have very similar environmental impact. Knowing that concrete blocks are among the products with the lowest environmental impact per square meter and that the one presented in table 1 is concrete block produced with energy efficient process, the SCCC proposed in this study is therefore a promising solution. Actually, most concrete blocks produced in developing countries have a higher cement content.

Furthermore, it seems important to point out that among the main contribution to the environmental impact, cement is not anymore the main one (compared to typical concrete block or concrete). In our product, due to the very small amount of cement used, the plasticizer becomes a significant contributor. It means that, at the difference with all cement based product, the SCCC developed here would have an improved environmental footprint when a more environmentally plasticizer would be used. Transfer of technologies not only from cement and concrete technologies but also from vernacular earthen construction could be a very promising option. Actually, it is known that during centuries some natural products were used as stabilizers, such as blood, urine, manure, casein, animal glue and plant juices *[17]*. Many innovative and environmentally friendly earthen materials have been developed through the use of biopolymers in various constructive traditions. Among all these biopolymer molecules, some of them can act as dispersing agents. This is the case of some organic acids like humic acid that can deflocculate montmorillonite particles *[18]*. Some tannins, which are polyphenolic molecules, can also play this role of dispersant *[19]*.

Conclusion and perspectives

Strategies that have been tested allow producing a material that can flow and be demoulded after 24 hours. Indeed the PCE used plays an important role on the deflocculation of the clays and allows SCCC: Self-Compacted Clay based Concrete. The defloculation role is more accentuate when the amount of calcium ion is high and the pH alkaline due to CSA. Then the transfer of physics and rheology principles used in concrete science can be used for clay based concrete. The use of CSA instead of cement is promising firstly due to its capacity to remove faster water and lower shrinkage during drying. More, we showed a rapid strength gain but a low impact on the final mechanical strength. The environmental assessment performed on the first prototype shows that it has a relatively low environmental impact and that it can be compared to concrete blocks. However, at the difference with concrete block, the environmental impact associated with cement compared to chemical admixture is very small, showing that further improvement in term of CO_2 emissions might come from a better used of plasticizers. In particular, using natural plasticizers which have often been used in vernacular earthen construction such as tanins would be a future promising research option. Finally, these initial experiments on the setting of the self-compacting clay concrete open a lot of questions on the mechanisms involved. The removal of the water needs to be understood in terms of chemically and physical bounding phenomena, cement reaction and drying.

Aknowledgement

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References

[1] R. Anger and L. Fontaine, (2009) “Bâtir en terre: du grain de sable à l’architecture,” in *Bâtir en terre: du grain de sable à l’architecture*, Belin editions. p. 223.

[2] J. C. Morel, A. Pkla, P. Walker, (2007) “Compressive strength testing of compressed earth blocks,” *Constr. Build. Mater.*, vol. 21, p. 303,.

[3] A. Shukla, G. N. Tiwari, and M. S. Sodha, (2009) “Embodied energy analysis of adobe house,” *Renew. Energy*, vol. 34, no. 3, pp. 755–761.

[4] M. L. Parra-Saldivar and W. Batty, (2006) “Thermal behaviour of adobe constructions,” *Build. Environ.*, vol. 41, no. 12, pp. 1892–1904.

[5] M. Schneider, M. Romer, M. Tschudin, and H. Bolio, (2011) “Sustainable cement production—present and future,” *Cem. Concr. Res.*, vol. 41, no. 7, pp. 642–650.

[6] R. J.-M. Pellenq, N. Lequeux, and H. van Damme, (2008) “Engineering the bonding scheme in C–S–H: The iono-covalent framework,” *Cem. Concr. Res.*, vol. 38, no. 2, pp. 159–174.

[7] K. Kovler and N. Roussel, (2011) “Properties of fresh and hardened concrete,” *Cem. Concr. Res.*, vol. 41, no. 7, pp. 775–792.

[8] J. Yammine, M. Chaouche, M. Guerinet, M. Moranville, and N. Roussel, (2008) “From ordinary rhelogy concrete to self compacting concrete: A transition between frictional and hydrodynamic interactions,” *Cem. Concr. Res.*, vol. 38, no. 7, pp. 890–896.

[9] N. Kang and H. Hwang, (2011) “Study on high strenghening of an earth wall using earth and high performance lime In: Heyzoo Hwang HG, and David Gandreau,” presented at the 2011 international conference on earth architecture in Asia. Mokpo, Republic of Korea.

[10] N. Roussel, (2012) “4 - From industrial testing to rheological parameters for concrete,” in *Understanding the Rheology of Concrete*, N. Roussel, Ed. Woodhead Publishing, pp. 83–95.

[11] N. Roussel and P. Coussot, (2005) “‘fifty-cent rheometer’ for yield stress measurements: From slump to spreading flow,” *J. Rheol.*, vol. 49, no. 3, pp. 705–718.

[12] K. E. Lloret, R. J. Flatt, M. Kohler, and F. Gramazio, (2013) “Apparatus and method for vertical slip forming of concrete walls. Patent pending.,”

[13] R. J. Flatt, (2004) “Towards a prediction of superplasticized concrete rheology,” *Mater. Struct.*, vol. 37, no. 5, pp. 289–300.

[14] F. Winnefeld and B. Lothenbach, (2010) “Hydration of calcium sulfoaluminate cements — Experimental findings and thermodynamic modelling,” *Cem. Concr. Res.*, vol. 40, no. 8, pp. 1239–1247.

[15] deLarrard F., (1994) “Optimization of ultra-high-performance concrete by the use of a packing model,” *Cem. Concr. Res. - CEM CONCR RES*, vol. 24, no. 6, pp. 997–1009.

[16] EPD, concrete block. (2014). Mur en maçonnerie de blocs en béton. NFP 01-010. Cerib, 31pp.

[17] A. Vissac, Fontaine Laetitia, and Anger Romain, (2012) “Recettes traditionnelles & classification des stabilisants d’origine animale ou végétale, report, Grenoble: CRAterre-ENSAG.”

[18] A. Majzik and E. Tombácz, (2007) “Interaction between humic acid and montmorillonite in the presence of calcium ions II. Colloidal interactions: Charge state, dispersing and/or aggregation of particles in suspension,” *Org. Geochem.*, vol. 38, no. 8, pp. 1330–1340.

[19] Olphen, Hendrick van, (1963) *An introduction to clay colloid chemistry, for clay technologists, geologists, and soil scientists*. Interscience Publishers-New York hardcover.

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Energy efficiency for the refurbishment of Mediterranean historical small town centres: a methodology

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Abstract: *Economical and energy restraint affecting Europe lead contemporary architecture to focus on the renovation of historical building stock. In need of enhancing the energy performance of the Italian cultural heritage, the aim of this research is to investigate a refurbishment model that supplies strategies for non-monumental historical districts for the fulfilment of the general criteria of cultural, environmental and economic valorisation through an integrated design that combines principles of innovation and conservation, minimum intervention and energy efficiency. Operating on the refurbishment of historical villages in central Italy, this paper focuses on the refurbishment of the historical rural burg "Le Pagliara"(Opi). A strategic framework seeks to reactivate and expand its original productive character; it aims at recovering the architectural typology while enhancing energy performances and achieving microclimatic comfort, in compliance with regulated performance requirements and innovative models of traditional spaces in terms of access, management and equipment.*

Historical districts retrofit, Technological&energy upgrading, ZeroGround consumption, Socio-economic revitalization,

State of the art

The directive 2012/27/UE on energy efficiency to be adopted by Member States in each legal order within the 5th of June 2014, sets common measures for energy efficiency promotion within the European Community. The most significant innovation is the introduction of energy refurbishment for existing buildings: Member States are supposed to adopt a long term strategy to mobilize investments for the energy renovation of the national building stock[1]. In particular, this strategy should include: a review of the national building stock; the identification of effective refurbishment approaches in terms of costs, building type and climate zone; an evaluation based on the expected energy savings and the benefits in the broadest sense. Along with cultural heritage protection projects [1], European Strategy on the Urban Environment [2] focuses on strengthening urban communities identity and enhancing urban quality of life, as a major opportunity to focus resources specifically for energy retrofitting of historic centres and districts [3]. As pointed out by 3ENCULT European project [4], historic building stock is extremely heterogeneous and requires specific interventions to protect and enhance its cultural value, assess and improve its energy efficiency. In fact,

[1] *For public buildings, the Directive establishes the obligation to upgrade central government buildings and to ensure the improvement of buildings under major renovation in order to meet minimum energy standards. In particular, it specifies that each Member State, from January 1, 2014, must ensure that 3% of the total useful floor area of the conditioned buildings public property of their central government (and its employees) is upgraded every year.*

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according to New4old European project [5], historic buildings have been gleaned through a long-time experience of trials and errors, which has encouraged the selection of effective passive constructive methods to provide a comfortable state both for living and general use, thus contributing to good energy performance for different climates.

To enable the process of eco-efficient renovation of existing buildings all operators in the market must be involved, starting from public authorities, to construction companies and designers. Something has to change not only in the perspectives of design and construction, but also in operational tools: adjustments will be necessary in areas such as financing structure, public procurement, education and marketing. It seems clear that the assumption underlying any *action plan* need to be aware of the typological and constructive characteristics and the energy consumption of 12.5 million buildings. In this perspective it is not enough to operate on individual buildings, but we must extend the upgrading operation to entire neighbourhoods and historical compounds as smaller towns and hamlets. In particular, CRESME [6] estimated that in Italy 1650 municipalities will be at "risk of extinction" in 2016[2]. In line with the prescriptions of the network HerO – Heritage as Opportunity [7], it is necessary to facilitate the right balance between the preservation of built cultural heritage and the sustainable, future-proof socio-economic development of historic towns, as a resource to be valued at ground zero consumption.

General goals and methodology

The urban fabric of minors historic centres should be reinterpreted as a living organisms that operate at macro-scale (the historical centre and the urban fabric) and micro-scale (the artefact in the process of conservation and refurbishment). Minor historical centres and hamlets are called to change their conformation and configuration in a tight relationship between history, culture and technology, through processes of development that are not only a series of measures aimed at raising the economic value of land and buildings, but at pursuing broader goals of architectural, energy, social, economic and cultural redevelopment and revitalization of the urban context to which they refer. To ensure that the process is not reduced to simple operations of real estate development, building restoration or urban make-up, it is necessary not only to leverage on existing resources and potential, but also to respond to the deficiencies of the urban fabric and to the demands of the socio-economic context. Moreover, it is critical to search for *transformation patterns*, that can be traced to two models of intervention: the first relates to the sphere of the purely "technological", meaning all matters relating to the conservation of places and/or artefacts with innovative and environmentally sustainable techniques and approaches to refurbishment; the second concerns the transformation processes that attempt to re-interpret the local historical and cultural contexts, renovated to attract new activities and interests. The so-called *ecological metabolism* [8] of historical buildings, meaning the passive behaviour and energy efficiency of traditional building systems, has often been underestimated or altered through time by an improper technological

[2] *Regarding the Italian situation, the national report "Riuso03[2]" (CRESME) states that in from 2006 to 2013, the national cost for building renovation was around 115 million euros, against the 51bil for new construction.*

implementation. The approach of this research is to highlight peculiar bioclimatic characters of the building typology and work for the restoration and enhancement of such systems through passive solutions and innovative technologies. We seek to identify the *additional identities* [9] (result of the building and district's evolution) and to assess whether they act as positive contributors to the district's correct functioning or invalidate its original passive behaviour. Staying in line with the principle of *minimum intervention* [10] on significant buildings, a correct use of most recent technologies for energy refurbishment provides non-invasive solutions that can be implemented with little or no significant impact on the overall appearance of the building while increasing its energy efficiency and assuring thermo-hygrometric, visual, and acoustic comfort, towards *compatibility and reversibility*. In a low energy approach, innovation that involves passive systems has to be fostered[3]. In order to respect these principles and formulate strategies for the existing structures [11], we outlined three intervention scenarios that express the level of respect/alteration of the historical-morpho-technological character and the fulfillment of performance requirements regulations for new uses of the buildings:

a) A *soft refurbishment scenario*, that includes operations that do not significantly alter the overall external appearance of the complex and introduce *essential* interventions for the enhancement of the energy performance and indoor comfort of the buildings.
b) An *intermediate refurbishment scenario*, that includes operations that slightly alter the external appearance of the complex, sacrificing additional identities or elements that have been altered over time, and can no longer be considered as essential parts of the original building. This scenario includes both essential and *advantageous* interventions.
c) A *hard refurbishment scenario*, that includes invasive operations the external appearance of the complex on determined elements designated as expendable, with possible volumetric modifications for the optimization of energy gains and minimization of losses with the use of essential, advantageous and *recommended* interventions.

Application on the pilot project

The study for the Rehabilitation of "Le Pagliare", the rural area of the small hamlet of Opi[4] (Im1), located in the core of the National Parc of Lazio, Abruzzo and Molise in central Italy, aims at identifying the tools and verifying the feasibility of the transformation of the rural complex in a touristic-didactic attraction that will maintain the original productive nature of the complex. The buildings that housed the former stables are connected by a dense network

[3] *Minimum intervention: to preserve the maximum of the historic fabric and the significance which it embodies - Compatibility: all changes should use materials and techniques compatible with the historic fabric - Reversibility: unavoidable changes that may be detrimental to the significance of a building should be fully reversible, whenever possible.*
[4] *The Municipality of Opi (AQ) is located on a hill in the upland of Alta Valle del Sangro, at 1150 m above the sea level, surrounded by montains reaching almost 2300 m. The hamlet probably founded in the Middle Ages is included in the list of the most beautiful hamlets of Italy and has a population of 441 inhabitants. The climate is particularly cold with an average temperature of 16,3°C in July and -0.8°C in January (climate zone F).*

of multiscalar relationships that need to be valorized to promote a socio-economic development, facilitated by the great natural value and sports tradition of the area[5].

In accordance with the historical-architectural value of the buildings, we mean to: assign new predominant functions to specific divisions of buildings, for a synchronic use of indoor-outdoor spaces and the enhancement of facilities management and bio-climatic performances; operate a typo-technological innovation, rethink models for traditional spaces in terms of use, management and equipment; recover and upgrade the original morphology where altered and protect emblematic details; achieve energy efficiency, thermo-hygrometric and psycho-perceptive comfort. The methodology of interventions is based on a qualitative – quantitative analysis of the de facto situation [9] [12]**,** that will point out:

1) *Territorial factors to determine the socio-economic success of the renovation project.*
2) *Morpho-techno-typological factors to determine the transformation feasibility,* simultaneously considering 4 subjects /issues:
    i. *The aggregate system.* The high concentration or the isolate position of buildings is a fundamental parameter for the comprehension of the fabric's behaviour within environmental conditions;
    ii. *Techno-morphological characteristics* allow to recreate the shape and the spatial organization of buildings, degradation level, materials and technologies of its components interfering on the energy behaviour of the structures;
    iii. *Uses*. If the calculation directives consider the use of spaces for their energy requirements, in vacant buildings it is necessary to consider the pre-existing and foresee use in transformations.
    iv. *Plant Systems.* When facing structures lacking such systems (as in our case), it is important to identify historical remains of their original passive operation, or the elements that, despite their original role, can be transformed in this sense.

[5] *The iconic complex consists of 10 structures built in the XVIII century to host farming activities, with a great historical and architectural value in state of decay The construction type, narrow units with small and few openings, hosting stables on the ground level and barns in the upper floor, are perfectly suitable for farming but challenging for transformation.*

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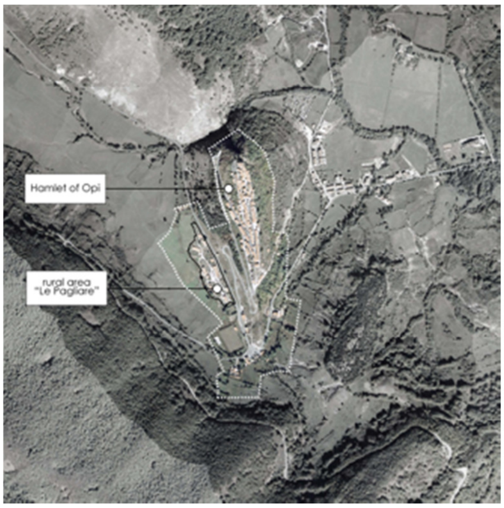

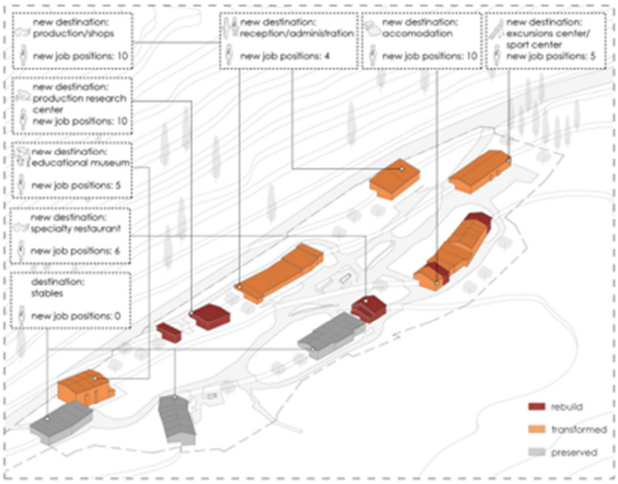

Im1_The hamlet of Opi and the rural area "Le Pagliare"
Im2_New functional asset of the area with a highlight on economic and social foreseen improvements. New destinations will be: agribusiness, production and craft area, pedagogical area, management area, hiking and sports centre, museum area, accommodation area and technological-research area.

The observation gathered in the first qualitative analysis have to be framed with the historic energy consumption data or analytic/simulative surveys when not available.

Output: Functional Refurbishment and Energy Retrofit Scenarios

In order to define the refurbishment scenarios, we need to determine the adaptability to transformation of existing constructions, according to indicators relating to:

- *Uniformity of current use* for indoor and in-between spaces allows to identify uniform divisions and reduces the need for displacements;
- *Accessibility* and proximity to roads influences the regulation of users/workers pedestrian or vehicular access, parking, load/unload cycles;
- *Alteration of original characteristics* enables to operate consistent transformations over buildings, if it does not compromise the overall historical value of the district;
- *Requirements adaptability* states the aptitude of the construction to positively respond to prescriptive requirements in the change of use. That includes safety, hygiene and healthiness of indoor spaces requirements;
- *Dimensions adaptability*. The fragmentation, distribution and dimensions of indoor spaces affects the kind of new functions that can be installed.

Within this framework we'll be able to define the new functional asset of the project area and define the technological upgrade that need to be carried on the buildings in order to actualize the transformation (Im2).

For the elaboration of energy and technological upgrading scenarios is necessary to recreate a plausible microclimatic comfort conditions and building energy performances by measurements and simulations.

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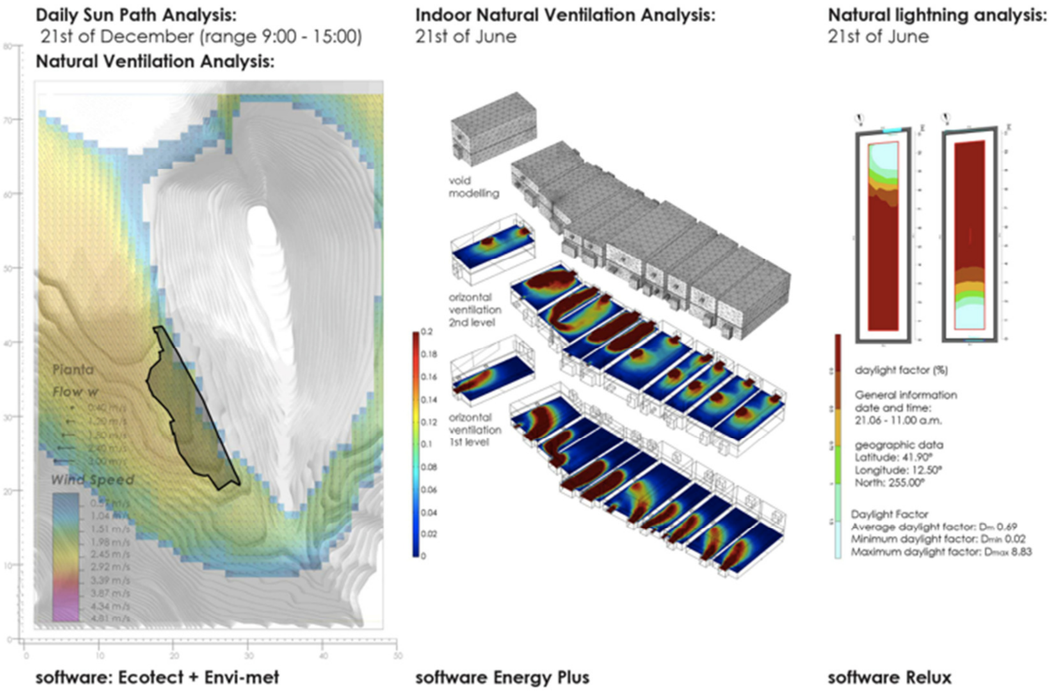

Im3_Ecotect Daily Sun Path and Envimet Wind Speed and Direction Analysis on the 21st of Decemeber
Im4_Energy Plus results on indoor ventilation (21st of June) show the wind speed: the air circulation (in red the 0,2 m/s zone with input wind at 0,35 m/s) mainly covers the half of each level in correspondence to the openings, leaving the other two halves isolated from ventilation.
Im5_Relux Analysis results (21st of June) show that, due to the small dimension of openings, even in best

The simulation on a wide scale with Envimet and Ecotect for natural ventilation and solar radiation shows that the mountain ring surrounding Opi valley causes a scarce degree of solar radiation in the NW side of the complex, slow down and channel the ventilation of the valley, mostly coming parallel to the longitudinal side of buildings (SE), and create ascendant/descendant ventilation phenomenon (Im3). The small dimension of openings and the geometric conformation of units negatively influence both natural lightning and ventilation, as verified with a computational fluid-dynamic simulation with Energy Plus (Im4) and the calculation of the daylight factor with Relux ($\eta<1$) (Im5). The thermal measurements on the building's envelope were influenced by the peculiarity of technologies (lacking heating systems, with a massive envelope in local stones and wooden/tiles roofs without insulation,) and use (mostly staples) and difficulty of access to all structures[6].

[6] *Because of the lack of heating systems, the thermal imaging had to be effectuated with the endogenous heat produced by animals in the staples during the night as the sole internal source of heating. The presence of animals prevented the use of probes for the definition of wall's internal temperature.* Im6_Thermal analysis through Ecotect simulations and Testo thermo-imagining. The thick stone walls reach a good thermal resistance even without an insulation layer, with a ΔT that can reach 10°C.

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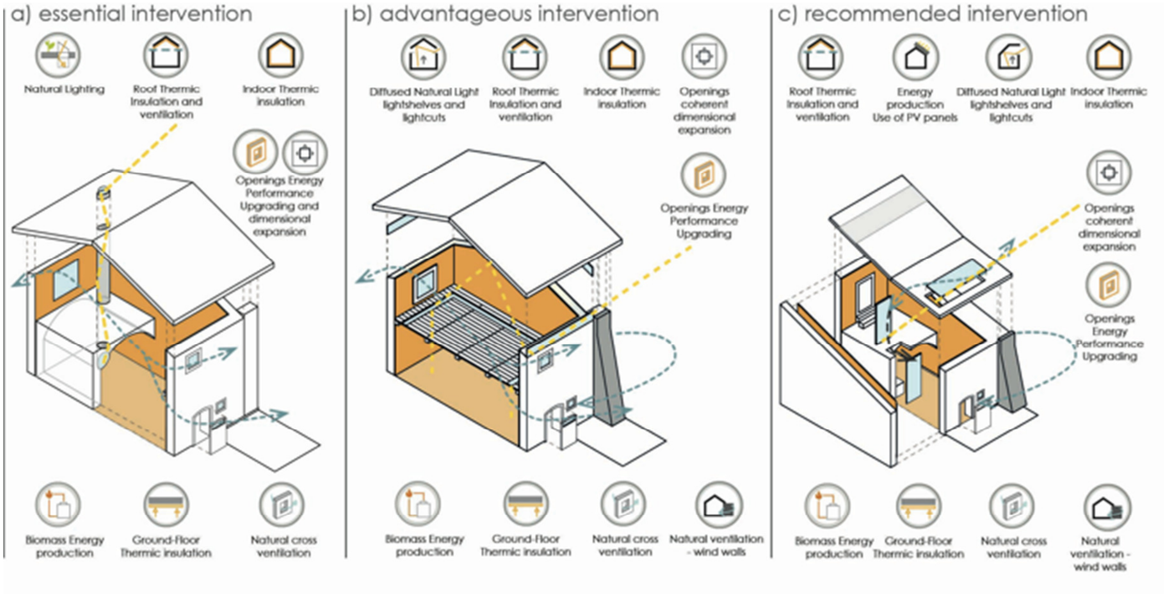

Im6a_In the softer scenario, natural ventilation and lightning is managed trough the opening of the upper part of the door elements to grant a natural crossed ventilation and the integration in the existing straw passage of solar-tubes. Windows extension is admissible if it respects original proportions and technique.
Im6b_In the intermediate scenario natural lightning and ventilation is manage through the elevation of the roof line (gaining height), openings, lightshelves and glazed cuts on the intermediate floor. Buttress will have the double aim of reinforcing the structure and act as wind wall, diverting wind direction inside the building.
Im6c_The hardest scenario completely reshape the roof line to improve light and wind grabbing. The glazed roof opening cooperate with thermal mass for heat stocking. The existing straw passage is used to increase

Therefore, the thermal performance of the enveloped had to be analysed with Ecotect and thermal-imaging with TEMA. Finally, a hypothetical energy certification with DOCET[7] shows a good summer behaviour of the buildings, but a very low general energy performance: 580 kWh/m2a energy consumption and 8,3kgCO2/m2a of CO2 emissions (G class).

In order to enhance passive performance for summer cooling, to enhance the overall energy performance of the building for thermal energy consumption and CO2 emissions, and to comply with regulation for daylight lightning (EN12464), it will be necessary to operate strategies according to the three scenarios of intervention (Im6 a, b, c). All of the three scenarios will be focusing on thermal insulation cooperating with wall thermal mass to mitigate winter temperatures. The choice of operating a continuous inner insulation coating is meant to respect the historical and aesthetical value of outer envelope[8]. Also, window frames and glazes will be replaced with high performing solutions in terms of thermal insulation, air tightness and transparency, coherent with the original materials finishing (wood). The installation of a biomass plant, fuelled by agricultural and wood manufacturing wastes, will produce hot water and centrally heating, to be distributed through serpentines under floor

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[7] *National regulation: DL 63 del 05 Giugno 2013 e successiva circolare n.12976 del 25 giugno 2013 – Ministero dello Sviluppo Economico; Norme Tecniche UNI TS 11300.*
[8] *Instead of using a traditional polymeric coating material (that will obstruct the natural functioning of thermal mass in day-night cycle), we'd chosen to use a 6cm layer of earthen plaster and wood fibres, will cooperate with thermal mass for thermal flow modulation and air quality control.*

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heating. Floors will be completely rebuild, in order to allow the insertion of ventilated under floor systems to prevent moisture problems.

Conclusions

In conclusion, renovation is meant not as simple protection and preservation of assets and resources, but as an action based on a general process of architectural, energy, social and economic revitalization. In the absence of a national specific regulation on energy upgrading of the built heritage, operational scenarios might require new arrangements with the current conservative regulations to carry out in partnership with local and regional authorities. To assess the feasibility of the intervention, it will be necessary to verify the willingness of owners to participate, with local assembly to discuss the transformation. Further modelling and simulations will define the best scenario for energy efficiency, adaptability, transformation and financial sustainability for the implementation of the project.

References

[1] European Union, European Commission, Directorate-General for Research and Innovation (2012) Cultural heritage research: survey and outcomes of projects within the environment theme: from 5th to 7th Framework programme. Luxembourg. EUR-OP.
[2] European Commission (2006) Thematic Strategy on the Urban Environment. Bruxelles. Office for Official Publications of the European Communities.
[3] Owen, L.J., Sadhbh, N.H. (2013) Building energy efficiency in european cities. URBACT.
[4] 3ENCult (2011) Report on demand analysis and historic building classification 2011.
[5] New4Old (2009) Technical guidelines for building designers
[6] CRESCME (2013) XXI Rapporto congiunturale e previsionale Cresme il mercato delle costruzioni 2013-2017. Rome. CRESME.
[7] HerO (2011) Heritage as Opportunity. 'The Road to Success' Integrated Management of Historic Towns GUIDEBOOK, Regensburg. Stadt Regensburg (available online at www.urbact.eu/hero)
[8] Davoli, P.M. ed. (2010) Il Recupero Energetico Ambientale del Costruito. Santarcangelo di Romagna. Maggioli Editore.
[9] Di Blasi, O. (2011) Progettare la modernità sulla preesistenza. In Malighetti, L. E., Recupero edilizio. Strategie per il riuso e tecnologie costruttive. Milano. Il Sole 24 ore S.p.A.
[10] Carbonara, G., ed. (2004) Atlante del restauro. Utet.
[11] Cecchini, C., Cimini, S., Morleo, R. M. (2014) Strategic scenarios in energy-environmental refurbishment of the historic massive building stock. Historical and Existing Buildings: Designing the Retrofit. An overviwe from energy performances to indoor air quality. Rome. AICARR.
[12] Battisti, A. (2010) Strategie sostenibili per il retrofitting degli edifici storici. Rivista Antincendio, Atti del Forum di Prevenzione Incendi (Milano, 19 ottobre 2010)

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Session 35:

How do lighting and ventilation influence user comfort in buildings?

Chairperson:

Gomes, Vanesa

Associate Professor. University of Campinas, Brazil

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Post Occupancy Evaluation of Shading Device for Elementary School Classroom

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Abstract: *Regarding the growth of the classroom shading device project in the Taiwan Sustainable Campus Program, this study made post-occupancy evaluation by taking three elementary schools in the Yilan area as the research objects. Research results showed the majority of users are satisfied with the shading devices. The shading devices can improve the classroom daylight quality. Although it can slightly reduce the amount of indoor daylighting, it has no clear effect on the improvement of the indoor thermal environment, and cannot produce definite energy efficiency. In addition, the effect of the shading device on the environmental education is not significant, and routine maintenance of the shading facilities still requires improvement.*

Shading device, post occupancy evaluation, environmental education, classroom, Taiwan

Introduction

The transformation of the traditional campus into a sustainable campus is an important goal of Taiwan's campus buildings. In addition to providing a high-performance learning environment, it can also serve as a living textbook for to support the implementation of environmental education in the classroom [1]. Amongst the numerous project applications for the Sustainable Campus Transformation Program funded by the government, the shading device has the dual purposes of energy conservation and indoor environmental quality improvement [2]. The shading improvement of the building's opening part is also an important objective of green building performance assessment in Taiwan [3]. Therefore, among the cases of implementation in the current Sustainable Campus Transformation Program, the increase of classroom shading facilities has become a common renovation project. However, for the current sustainable campus program, the effectiveness of increasing classroom shading devices toward the improvement of the indoor environment and the effectiveness of its application in environmental education is not clear yet, requiring further exploration. Therefore, based on the concept of building post-occupancy evaluation [4], this study took as objects the three elementary schools in Yilan area that first received the subsidy from the Sustainable Campus Program to set classroom shading devices in order to inspect the improvement of the buildings' physical environments after the installation of shading devices in windows, as well as the effectiveness of the school's environmental education in this regard, and to check the devices' typical use, maintenance and management. The results of

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this study can be used as reference for schools with the intention of setting up shading devices.

Research Methods

Five research methods were used in this study, namely, a literature review, field measurements, behavior observations, questionnaires and user interviews. The description is as follows:

1. Literature review: this was used to clarify the composition and operation principles of classroom shading devices. The shading devices in the three schools were different, including metal movable exterior vertical louvers, perforated metal movable exterior vertical louvers, and metal movable exterior horizontal louvers (Table 1, Fig. 1).

Table 1. Case Shading Basic Information

Case Number	Orientation	Type	Color	Leaf Width/ Spacing
Case A	ESE	Metal movable exterior vertical louvers	White	38 CM/20 CM
Case B	W	Perforated metal movable exterior vertical louvers	Light blue	38 CM/40 CM
Case C	N	Metal movable exterior horizontal louvers	White	11 CM/10 CM

Fig. 1. Case Study Shading Device Appearance

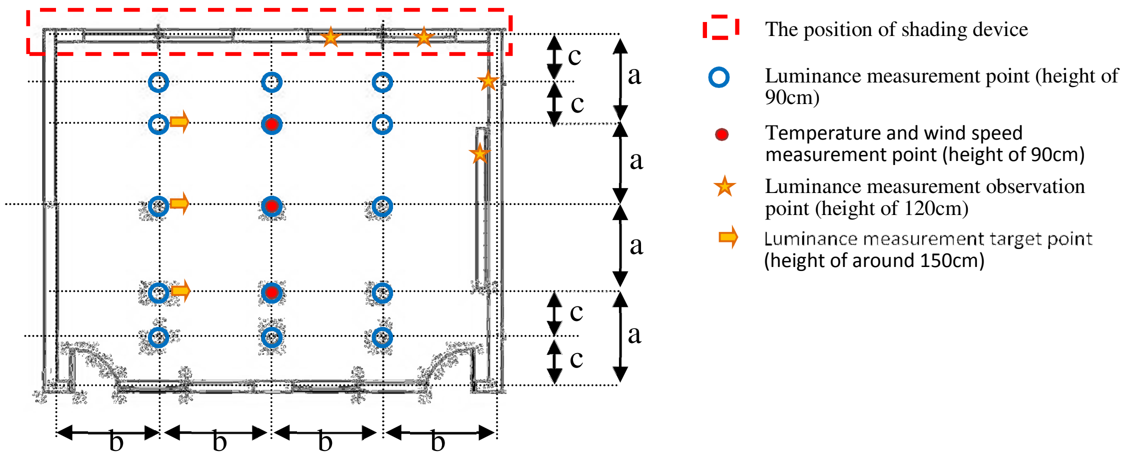

Fig. 2. Field Measurement Indoor Physical Parameter Point of Measurement

2. Field measurement: used to collect physical parameters of the lighting environment and the thermal environment of the classrooms with shading devices and classrooms without

the shading devices (the control classrooms), and to perform analysis of the classroom daylight factor, average uniformity of daylight, and window glare. The lighting environment field measurement of each case includes (Fig. 2): 15 points of indoor illumination desktops, shading device side windows and the adjacent wall luminance 4 points, and outdoor global sky illumination 1 point; the measured parameters of the thermal environment include (Fig. 2): indoor air temperature and wind speed 3 points, and outdoor air temperature and wind speed 1 point. The dates of measurement were one sunny day in summer and autumn, respectively. Lighting environment measurement was once in the morning and afternoon respectively, with lighting environment physical parameters of fully and half-open louvers. In the thermal environment, from 8:00am to 4:00pm, louvers were adjusted to the fully open state, and the physical parameters of the thermal environment were gradually measured in 10-minute intervals.

3. Behavior observation: directly observed interaction between the user and shading device and the effectiveness of the shading device on classroom lighting environment in situ. The observation time of each case was a four-day observation, recording from 8:00am to 4:00pm in sunny and cloudy weather in both summer and autumn.

4. Questionnaire: used to clarify daily use status, maintenance and management status, application status in the environmental education course of the shading device, and satisfaction with the shading facilities, recommendations, etc. The objects of the investigation were teachers and students using classrooms with shading devices; effective questionnaires of 36 teachers and 180 students at three schools were completed.

5. User interview: interviewed one shading device maintenance management person from each school to understand the daily use and maintenance management status of the shading facilities. Interview content included shading device daily operating conditions, routine inspection maintenance items, frequency and implementation, as well as common project faults, etc.

Results Discussion

According to the plan content of classroom shading devices applied by the schools and the related description of the classroom shading device in the "*A Guide to Sustainable Campus Construction*" [2], the ideal shading device shall allow the classroom indoor physical environment to produce an increase in daylight, glare prevention, indoor temperature reduction, natural ventilation guidance, and improvements of other aspects of the indoor physical environment, thereby producing energy-saving and carbon reduction benefits in classroom electric power consumption. To this end, this study made post-occupancy evaluation on the expected shading device effectiveness for improving the indoor daylighting and thermal environment, the teaching effectiveness of the device being used as environmental education teaching materials in the Sustainable Campus Program, daily use of shading facilities, maintenance management status and user satisfaction, etc.

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1. Indoor physical environment: For the quality of natural lighting, this study reviewed the classroom daylight factor, average uniformity of daylight, and window glare, and the results are shown in Table 2. After the installation of the shading devices, the classroom daylight factors of the three cases were reduced 15% - 55% of original value; when the shading device was fully open (the louver and window surface are in a vertical position), the daylight factor of all classrooms could reach up to 2%, the recommended classroom daylight baseline value [5]; when the shading device was half-open (when the angle between louver and window surface is 45 degrees), only one case could meet the 2% daylight factor baseline value. As for average uniformity of daylight, the natural average uniformity of daylight of all classrooms increased 1/20 - 1/5 of original value because of the installation of the shading device, and the case average value increased by 13%. For window glare, the luminance ratio between the window and adjacent walls of classrooms without shading devices exceeded the recommended baseline value of 1:20 [6], so it was not consistent with the recommended baseline; whereas the luminance ratio of classrooms with shading devices could be reduced to the recommended baseline value. In general, the shading device with larger louver leaf width and wider louver leaf spacing had better performance than the shading device with smaller louver leaves in terms of daylight factor and window glare. The shading device with small leaf surface and small spacing had better average uniformity of daylight, but resulted in a significant decrease in the daylight factor, resulting in inadequate indoor natural lighting.

Table 2. Analysis Results of the Measured Value of Shading Device Effectiveness on Classroom Indoor Physical Environment Evaluation Factors

	Status of louvers	**Average daylight factor(%)**	*S.D.*	**Average uniformity of daylight**	*S.D.*	**Average luminance ratio of window and adjacent wall**	**Average indoor and outdoor temperature ratio**	*S.D.*	**Average indoor and outdoor wind speed ratio**	*S.D.*
Case A	No louvers	*3.3*	*0.8*	*34.0%*	*7.2%*	*21*	*96.3%*	*1.9%*	*19.0%*	*5.3%*
	Fully open	3.1	0.7	40.1%	5.1%	8	96.5%	1.9%	50.3%	16.4%
	Half-open	2.6	0.4	38.5%	6.2%	2	-	-	-	-
Case B	No louvers	*2.2*	*0.4*	*77.6%*	*15.1%*	*37*	*98.4%*	*1.6%*	*17.6%*	*13.8%*
	Fully open	2.0	0.4	79.2%	16.2%	11	99.1%	1.7%	7.6%	3.3%
	Half-open	1.4	0.3	82.2%	13.7%	4	-	-	-	-
Case C	No louvers	*3.5*	*1.0*	*69.2%*	*14.6%*	*22*	*97.3%*	*3.7%*	*40.6%*	*38.0%*
	Fully open	2.0	0.4	84.3%	16.0%	18	96.9%	4.2%	9.0%	15.3%
	Half-open	1.3	0.4	82.3%	6.5%	15	-	-	-	-

On the quality of the indoor thermal environment, this study reviewed the average indoor to outdoor temperature ratio and the average indoor to outdoor wind speed ratio (Table 2). Indoor to outdoor temperature ratio refers to the ratio of indoor to outdoor temperature (= indoor air temperature / outdoor air temperature) at the same point in time; indoor to outdoor wind speed ratio (=indoor wind speed / outdoor wind speed) refers to the ratio of indoor and outdoor wind speed at the same point in time. Measurement results showed that the settings of the shading device had no significant impact on the ratio of indoor to outdoor temperature, and had no significant indoor cooling effect. Two cases even showed a very slight temperature rise after the installation of the shading devices. On the other hand, in terms of the indoor to outdoor wind speed ratio, two cases showed significant

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reduction after the installation of the shading devices, which meant the indoor wind speed had lowered significantly; but the other one showed significant increasing. So there was no consistent trend between the cases. However, it is worth noting that in case C with dense louver spacing, the indoor wind speed was significantly reduced due to being hindered by shading louvers. On the whole, the shading device had no significant impact on classroom indoor temperature, but it produced a significant influence on indoor wind speed, though it may have increased or reduced the indoor wind speed.

2. Environmental Education : Survey results showed that only 16.7% teachers used shading devices as teaching materials for environmental education at least once; while students said the ratio of shading device related environmental education courses was only 14.2%. Overall speaking, there was no definite effect of applying shading device in the promotion of environmental education in the case schools. On the other hand, it can be seen from the user interview results, based on safety considerations, teachers avoided letting students in lower grades operate the shading devices. Furthermore, for students, angle adjustment of the louvers was not easy. So when louver angle adjustment was required in daily use, it was mostly made by teachers, though they were adjusted by students in a few instances. Thus, only about 18% of students operated a shading device at least once, and interaction between students and the shading devices was infrequent. The aforementioned reasons, coupled with shading device being a classroom fixed device made it less attractive to students; if the shading device was used as a teaching material, it was prone to the impact of the outdoor climate and time conditions; consequently, most teachers had no intention to apply it in environmental education. However, it can be seen from the cross-over analysis of the questionnaire and the user interview results, the implementation of the shading device related environment education course can improve the interaction between teachers, students and shading devices, thereby improving the probability of sound operation and utilization of the shading devices.

3. Device Use Status and Maintenance : It can be found through behavioral observation that on the condition of proper operation of the shading device louver angle, the shading device could effectively block the direct sunlight into the classroom. The degree of operation convenience also had significant impact on the user operation wishes. In the cases of inconvenient shading device operation, users almost could not make the corresponding louver angle adjustment according to the external climate state, and therefore let the louvers always remain in a nearly fully open or closed state. For cases with louvers always in the fully open state, curtains were used to block direct sunlight into the classroom and artificial lighting was used to make up for the lack of interior illumination. For cases with louvers always in the fully closed state, artificial lighting was required to provide the needed illumination all day long. In addition, it is worth noting that due to a lot of big perforation in the louvers in case B, many shadows appeared on desktops when the sunlight shone through the perforations (Fig. 2), resulting in discomfort from the glare; this situation also forced the user to add curtains and use artificial lighting for an improvement (Fig. 3). Thus, in general, lack of good daily operation or shading devices with a poor

louver mode or angle adjustment switch did not only reduce the use of artificial lighting, but may have generated the opposite effect and could not produce the expected benefits of energy conservation and carbon reduction.

On the other hand, as teachers and students lacked shading device maintenance knowledge, the shading devices' regular inspection and daily maintenance in all cases were almost all completed by specialized personnel. In all cases, the school workers conducted shading device appearance inspections every six months to visually check the louver surface and shaft for damage and performed simple maintenance by adding lubricant to the shaft; when damage was found, professional manufacturers were responsible for repairs. The common fault locations on the shading devices were the louver angle adjusting switch and the louver shaft. In addition, the daily cleaning of shading devices were made irregularly; only when serious dirt was found by the user would school workers (occasionally teachers using the space) be responsible for cleaning.

Fig. 2. The Louver Cannot Completely Shield the Direct Sunlight Due to Big Perforations.

Fig. 3. Add Curtain in the Classroom and Turn on Artificial Lighting to Solve Shading Failure.

4. User Satisfaction: Survey results showed that both teachers and students tended to be satisfied with the shading device installed; the proportion of students with positive feelings (46.4%) was slightly higher than that of teachers (44.0%); the proportion of students (6.9%) with negative feelings was similar to that of teachers (6.5%). On the other hand, on the topic of "Promoting the Installation of Shading Devices", except for only 33.3% teachers agreeing to continue the promotion in case C, more than 50% of teachers in the other two cases supported continued promotion. The reason for teachers not being in favor of shading device installation in case C was the adverse effect on indoor ventilation; along with factors such as difficult shading device operation, the proportion of teachers in this school with negative feelings toward the installation of shading devices was higher than the other 2 schools. This situation made more than 20% of teachers think the installation of shading devices should not continue.

Conclusions

1. Daylight quantity and quality: the shading device can effectively block direct sunlight into the classroom, significantly improve the classroom average uniformity of daylight (the case averages can improve up to 13% of original value) and window glare, but it will also reduce the classroom daylight quantity (the case average was about a 30% reduction).

2. Thermal environment: the shading device has no significant effect on lowering the room temperature, and will affect the indoor natural ventilation. Especially in the case of densely spaced shading devices, the ventilation obstruction is more serious.

3. Environmental education: more than 80% of students didn't receive the shading device related environmental education course, and the interaction between teachers, students, and shading devices was poor. For safety reasons, teachers avoided letting students in lower grades to conduct shading device operation and maintenance. For teachers, the reasons for shading devices being unsuitable for environmental teaching materials were: difficult operation, it was a mundane device which was less likely to arouse students' interest, and the implementation of courses were subject to climate conditions and time constraints. However, the implementation of shading device environmental education courses would enhance the probability of interaction between teachers, students and shading device.

4. Use and maintenance: the convenience of shading facilities operation significantly affects the user's desire to operate. In cases with low shading device operation probability, the probability of artificial lighting will increase. Shading devices unable to fully block direct sunlight in the open state and improve window glare will force the user to give up daylight utilization but will use artificial light to meet indoor light environment quality needs, which may actually increase the amount of lighting energy consumed. In all cases, the shading devices were checked every six months, but the daily cleaning of shading devices was performed irregularly. Surface cleaning was required only when serious dirt is found.

5. User satisfaction: teachers and students tend to be satisfied with the installation of shading devices, and most teachers support the continuation of shading device promotion. The primary causes of user dissatisfaction are inappropriate louver dimensions (dense spacing or inadequate louver width) and inconvenient switch operation (the switch position is too high or outside the window, and great effort is required for operation).

References

[1] Hsieh, H.R. (2013). Case Study on the Environmental Education Application Status for Water Recycling Facilities in Elementary and Junior High Schools in Yilan. *Applied Mechanics and Materials*, 284-287: 1453-1457.

[2] Su, H.J. (2006). *A Guide to Sustainable Campus Construction*. Taiwan. Ministry of Education.

[3] Constitution and Planning Administration. (2009) *Design and Technique Specifications for Green Building Structure*. Taiwan. Ministry of the Interior.

[4] Preiser, W.F.E. (2003). Continuous Quality Improvement through Post-Occupancy Evaluation Feedback. *Journal of Corporate Real Estate*, 5(1): 42-56.

[5] Chiang, C.M. (1997) *Physical Environment of Building*. Taiwan. San Min Book co.,Ltd.

ISBN: 978-84-697-1815-5

[6] IESNA. (1988) *American National Standard Guide for Educational Facilities Lighting*. USA. Illumination Engineering Society of North America (IESNA).

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Control of Indoor Climate Systems in Active Houses

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Abstract: *The term of “Active House” recently developed, addressing houses which target a balanced optimization of indoor environmental quality, energy performance and environmental performance. A lively international network, the “Active House Alliance”, has been founded and numerous pilot projects in a widespread range of nations and climates have been erected.*

The paper in hands presents outcomes of a recently finished study by the autor (1), investigating the apropriate design and operation of indoor climate control systems in Active Houses. It is based on the experience from the six VEUX model homes 2020, supplemented with inputs from desktop research and own experience.

Part One, Theory, provides 1. basics on Active Houses and 2. a discussion of Indoor Environmental Quality targets. Part Two, Applications, draws conclusions, 3. providing the challenges of and 4. recommendations for designing and operating indoor climate control systems in Active Houses.

Main learnings and conclusions are:

1. Active Houses are fast reactive towards direct sunlight. Thus, an effective and fully automatically controlled system of movable shadings is obligatory for achieving good summer comfort.

2. Hybrid ventilation systems stand the test, combining automated window operation, and mechanical ventilation systems as well as manual window operation. The learning is to consequently separate the operation periods of automated window and mechanical ventilation, depending from outside temperature.

3. Beyond technical automation it’s essential offering intuitively manually operable devices such as windows, doors, awnings. Furthermore it’s preferable having some devices literally manually operated than having them only manually telecommanded.

4. Sun protection together with night ventilation is an effective combined strategy towards summer comfort, which turned out to be preferably automated. At least in central and northern Europe areas there turned out to be a somehow weak intuitive understanding of heat protective building operation.

Key words: Active Houses, Indoor environmental control, daylight, hybrid ventilation

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Introduction

The paper in hands presents outcomes of a recently finished study, investigating the apropriate design and operation of indoor climate control systems in Active Houses. It is based on the experience from the six VEUX model homes 2020, supplemented with inputs from desktop research and own experience.

Part One, Theory, provides 1. basics on Active Houses and 2. a discussion of Indoor Environmental Quality targets. Part Two, Applications, draws conclusions, 3. providing the challenges of and 4. recommendations for designing and operating indoor climate control systems in Active Houses.

1.1 Active Houses - Goal and Definition

Goal and definition of Active Houses is precisely but still lively and even poetically defined in the Active House Specifications (2), structured in three fields of concern:

Indoor Environmental Quality:
An AH creates healthier and more comfortable life.
An AH ensures a generous supply of daylight and fresh air.

Energy
An AH is energy efficient.
All AH's energy needed is supplied by renewable sources.

Environment
An AH interacts positively with the environment
through an optimized relationship with the local context.

It's this balanced approach towards Comfort, Energy and Environment that makes the Active House quite unique amongst other building standards and which, indeed, is the origin of some challenges, not least in technical control systems.

1.2 The model home 2020 research program

From 2010 to 2013 six model homes in Active House Standard have been erected and monitored in five European countries, funded by the company of VELUX. Altogether, this "model home 2020" program was the biggest concerted applied research action in the field of Active Houses. For further information see
http://www.velux.com/sustainable_living/demonstration_buildings

2.1 Discussion of Indoor Environmental Quality Targets

Indoor Environmental Quality, often but improperly referred to as Indoor Comfort, is a major issue of today's building design research. Design decisions towards Indoor Comfort are intrinsically linked to the energy demand of buildings. And, which is overseen too often, Indoor Environmental Quality is not only about comfort but it's very much about health. This correlation is gaining importance rapidly, with today's urban lifestyle leading to 95% of the lifetime being spent indoors. Not at least regarding daylight there's strong evidence for severe health-threats origin from a lack of daylight as regards quantity as well as quality, e.g. investigated in the Author's dissertation thesis (3). Thus, it is important to discuss Indoor Comfort very much together with Indoor Health. In building design indoor health is a "must have" issue and indoor comfort is a "nice to have".

2.2 Thermal Comfort Targets in Active Houses

Regarding indoor comfort, Active Houses strive for an equally high level of thermal comfort, qualitative daylight supply and air quality. Further criteria are listed in the Active House Specifications. Based on these comfort criteria Active Houses in most cases are intensively linked to the outdoor conditions.

Thermal comfort targets for Active Houses are defined according to the adaptive comfort model for dwellings without mechanical air conditioning, otherwise with stepwise levels for maximum and minimum operative temperatures. This definition follows closely EN 12251, Appendix 2 (4) and ASHRAE Standard 55 (5). Thus, the Active House specification allows indoor operative temperatures within, relative to ISO 7730 (6), an extended band, justified once more by the deliberate linkage of Active Houses to the outdoor environment, being regarded as strength and not as weakness.

3 Challenges of technical IEQ control systems in AH

As a conclusion from, the characteristics of Active Houses, the Indoor Environmental Quality targets and the characteristics of technical comfort control including personal intervention, the following challenges of Indoor climate cControl systems in Active Houses occur:

3.1 Challenge of intensive climatic connection to the outdoors

Active Houses tend being generously daylit, generously supplied with fresh air and significantly connecting to the out-of-doors. Thus they are fast and strong reactive to sun, wind, outdoor temperature, noises and air quality. In cold climates, the feature of window ventilation has to be balanced against energy loss and draft risk. In warm climates, the generous daylight supply has to be balanced against overheating risk.

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3.2 Challenge of Hybrid Ventilation and Hybrid Air Conditioning

Active Houses’ characteristics of intensive climatic connection to the outdoors can be met by hybrid operation, with either allowing free running mode or apply automated control of indoor environmental parameters. Hybrid ventilation and Hybrid Air Conditioning is a good and promising option, but contains the challenge of effectively defining the changeover points between manual, automated or even combined control.

3.3 Challenge of perceptibility of automated windows and sunblinds

In Active Houses, windows and sunblinds are most important components of indoor environmental control. As already mentioned, it’s very much recommended to automate their operation. Still, very much different from most of the other control components, the automated operation of windows as well as of sunblinds is most obvious and perceivable: Inhabitants see and hear the windows being opened and closed. They see and hear the sunblinds go up and down. This will always generate a mental reaction, positive or negative, instantaneously influencing individual comfort. The control algorithms have to be programmed with special care for the user’s reaction.

3.4 Challenge of automated convenience versus free running perception

Active Houses target to offer a high level of comfort, but still target to be perceived as free running mode buildings as much and as often as possible. Free running perception together with personal adaptive options is known to form the “Forgiveness Factor”. AC in sharp compliance with technical comfort parameters does not. Thus, building automation in Active Houses has to be introduced in support and not in substitution of individual adaptive options.

4 Learnings and Recommendations

4.1 Recommendation for Single Room Control regarding Heating

Today’s homes are equipped with automated heating system, controlling the indoor air temperature. There’s no exception with Active Houses. It’s our recommendation always automating the heating on a thermostat-controlled basis with single room controllers, allowing specific temperature setpoints for different rooms, what is especially beneficial in case of sleeping rooms. Furthermore it’s our recommendation not linking the flow temperature of the heating circuit to the outside temperature, because in passiv solar driven houses occurrence of maximum heat load doesn’t correspond with occurrence of minimum outside temperature.

4.2 Recommendation for automated Sunblind Control

All model homes are equipped with automated sunblind control. Not as a surprise it turned out being a crucial feature for overheating protection. The technologies are ready. Still, attention must be paid to the control algorithms: Sunblinds have to be controlled by solar irradiation, never by room temperature. The automated sunblind control may be switched off in spring, autumn and winter. Sufficient setpoints for closing the sunblinds are 120 to 180 W/m² irradiation at the specific façade. Automated wind and rain protection is a must. The control should avoid short time interval operation. It ‘s favorable to integrate a hysteresis of minimum 30 W/m² and time-lag of at least 15 minutes before reopening the sunblinds.

4.3 Recommendation regarding window opening control

Automated windows are a frequently used component in Active Houses, supplying both hygienic air exchange (comfort ventilation) and Ventilative Cooling (night flush ventilation). Learnings from the model homes are:

It’s favorable to position automated windows for comfort ventilation, at a level of 2 m and higher, to design them low but wide, to operate them as top hung or pivot hung windows. They proved to be much better adjustable and much less draft risky than side hung windows with vertical orientation. Besides, roof windows fulfill these criteria to a high extent.

Only during the first months after moving into the new homes, inhabitants reported being disturbed by noise emitted by the actuators. They got used to it quickly. Still, algorithms of automated windows should be set in a way to avoid high switching frequencies.

Regarding night ventilation, a simple time-dependent operation proofed good success, possibly combined with an outside-temperature command. Regarding operation of comfort ventilation, again, the automated control should avoid short time interval operation. We recommend a hysteresis of minimum 200 ppm CO2 and time-lag of at least 30 minutes before reopening the ventilation windows.

4.4 Recommendation regarding automated night ventilation

The six model homes are located in Europe, from 48° to 57° northern latitude. Most of them haven’t been equipped with technical cooling, but all of them with automated sunblinds and with automated night ventilation. It worked up to the expectations, if automatically controlled.

Astonishingly enough, if people overrode the building automation regarding Ventilative Cooling and sunblind control they made it worse. Middle and northern Europeans don’t seem to have a well-equipped intuitive understanding for sun and heat protection. Thus, it’s our recommendation to always automate Ventilative Cooling together with sunblind operation.

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4.5 Recommendation regarding Hybrid Ventilation Systems

All model homes are equipped with automated windows for both Ventilative Cooling and comfort ventilation. Many of the houses are additionally equipped with mechanical ventilation systems. Regarding hybrid ventilation it was a significant learning to properly and strictly define the switchpoint when automated natural ventilation stops and mechanical ventilation with heat recovery takes over. From theoretical analysis and from practical experience a one hour mean value of 10°C and 14°C outside temperature proved to be a good choice regarding energy optimization as well regarding comfort. We do not recommend parallel operation of comfort ventilation by automated windows and mechanical ventilation.

4.6 Recommendation regarding User Information

The model homes have been equipped with extensive monitoring and control devices. Users have been informed via wall-mounted info screens, informing about air temperature, VOC, humidity, energy consumption and supply and others. Via touch panel setpoints may be changed. The complexity of the systems was driven by research aspects and caused a lot of of questioning and observation if this system is user friendly or if it’s over-sophisticated.

During their first months in the homes, some users felt overloaded by all the options of the system, but after users got used to the system, those complaints disappeared. About half of the users settled to not changing any setpoints apart from simple room temperature. The other half actively used the options for personalizing the control system. We conclude, user information and central control is a beneficial but not a crucial feature of technical control systems in Active Houses.

User information may go one step further, starting from only informing about specific values and key qualities, on to giving feedback on the thermal status of the house, even towards giving suggestive feedback to the user, e.g. regarding closing or opening doors, e.g. switching on or off internal loads and else.

4.7 Recommendation regarding Artificial Light Control

Automation of artificial light operation, including movement sensors and illumination correlated dimming, is a well-established standard in modern offices. In homes, it’s our experience and recommendation to leave the control of artificial light to the user, since the choice for or against having the lights on in a home depends from much more parameters than illumination level and therefore should stay a personal decision.

References

Holzer P. (2014). Control of Indoor Climate Systems in Active Houses. Unpublished

Active House Alliance. (2013). Active House Specifications, 2nd edition, http://www.activehouse.info/download-specifications (23.08.2014)

Holzer, P., Hammer, R., Krec, K. (supervisor) (2009). Quality and Quantity of indoor daylight supply. Potential study specifically taking into account the radiation induced thermal indoor quality and the human photophysiology. Technical University Vienna, 2009.

EN 15251 (2007). Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics.

ASHRAE Standard 55 (2013). Thermal Environmental Conditions for Human Occupancy.

ISO 7730 (2005). Ergonomics of the thermal environment -- Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria.

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Passive Cooling by Ventilated Façades in Streets Canyons under Climatic Summer Conditions in Southern Europe

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Abstract

In this work we study the effect of passive cooling of buildings in urban canyons in the summer operating conditions in Southern Spain by using ventilated façades. Under these climatic conditions, indoor comfort implies a high energetic demand during summertime.

Ventilated façades, if well designed, can significantly reduce this demand, especially in situations of high solar irradiation. Some authors describe the energetic efficiency decline of these façades when the ambient temperature is high . This phenomenon might worsen because the specific thermodynamics of urban canyons can increase the flow of hot air inside the ventilated chamber.

The aim of this work is to determine if during summer operating conditions in Southern Spain, when high values of solar irradiation and temperature are common, ventilated façades in urban canyons provide some energy saving compared to the non-ventilated façades and to deduce their behavior patterns in terms of energy efficiency.

***Keywords:* passive cooling, ventilated façades, energy-efficient building, urban canyons, CFD, FEM.**

Introduction

Over the last years, interest in the development of passive systems for heating and cooling has experienced a remarkable rise because of the need to decrease the energetic costs in the thermal conditioning of buildings.

The aim of this paper is to analyze the heat transfer through a system consisting of a ventilated façade used in a building in urban canyons under the operating conditions of summer weather in southern Spain, and to determine if under such conditions the studied ventilated façade provides some energy saving compared to the non-ventilated façade, and to deduce their behavior patterns in terms of energy efficiency.

Specifically, we consider the typical values of temperature and radiation for the whole period of a year for the city of Seville and this for the orientations East, South, West and North.

In hot climates, the main advantage attributed to ventilated façades is the reduction of cooling load for the building climatization. This reduction is achieved by the combination of two factors: ventilation induced by natural convection in the ventilated chamber and the protection from solar radiation provided by the external layer of the façade.

However, while it is possible to guarantee the performances of a mechanical ventilation system, this is not necessarily the case for natural ventilation because, essentially, the performances of natural ventilation are subject to the influence of meteorological conditions (wind, ambience temperature and solar irradiation) and the urban environment.

Indeed urban canyons present patterns of thermodynamic behavior that can strongly affect heat flow into buildings and alter the thermodynamic behavior of the ventilated façade. Such a paterns are characterized by the urban canyon morphology that has a decisive effect on radiant exchange, energy storage and wind flow. Incoming solar radiation is absorbed over a much larger surface area compared to open sites and the amount of absorbed radiation is conditioned by the shadows that buildings project each other. This way, each building façade are exposed to direct sunlinght for only several hours of the day. This results in reduced insolation of each building façade, especially in canyons with hight ratio between height of buildings.

Furthermore the long-wave radiation exchange between the surfaces of the urban canyon is larger than in open spaces while the long-wave radiant loss is inhibited by the small sky view factor that urban canyons exhibit.

The physical model

We consider a ventilated façade in a building located in the middle of an urban canyon whose dimensions are 300 meters long, 25 meters wide and a mean height of 30 meters for buildings that make up the canyon. For example these dimensions can be found in the República Argentina Avenue in Seville (Spain). The Fig.1 shows a schematic section of the ventilated façade.

The heat transfer in the ventilated façade is determined by:

- Heat gain on the outer slab due to solar irradiation.
- Heat exchange by radiation between the outer surface of the façade and the other urban canyon surfaces.
- Heat exchange by convection between the outer surface and the ambient air. For this exchange, we use the correlation $h_c = 1.7\, U_{loc} + 5.1 \; \frac{W}{m^2K}$ given by Sharples in [1], where U_{loc} is the wind velocity in m/s measured near the surface of the façade.
- Heat transfer by conduction through the outer slab.
- Radiative heat exchange between the two surfaces which delimit the ventilated chamber.

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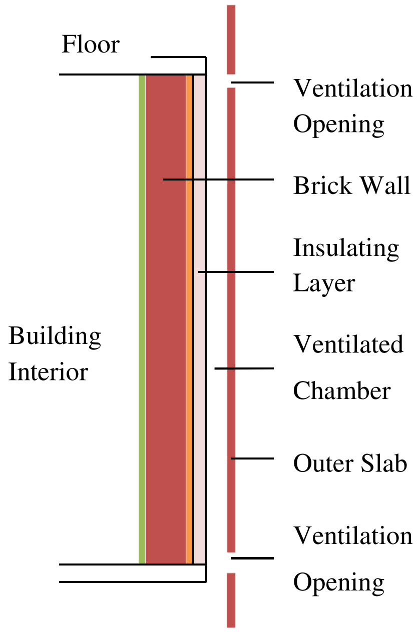

Fig 1 Section of the Ventilated

- Convective heat exchange between the surfaces of the ventilated chamber and the air flowing inside it. For this exchange the convective heat transfer used has been the provided by the Gnielinski formula for convection in ducts.
- Heat transfer by conduction through the inner wall.
- Heat exchange by convection and radiation between the internal surface of the inner wall and the interior of the building. Here we have used a mixed heat transfer coefficient $h_i = 8\ W/m^2K$, which is usually recommended in the technical specifications for this type of indoor heat exchange.

Solar radiation gain and long wave radiation exchange

The total irradiation for the urban canyon surfaces is the summation of the direct, diffuse and reflected solar irradiation. They have been calculated with steps of ten minutes in the 15th day of every month of the year. The three types of radiation takes place only for the sunny area of each surface, whereas that shaded areas are affected only by diffuse and reflected irradiation. In order to calculate these irradiation values, shaded and sunny areas of each surface have been calculated for the same time intervals.

The effective value considered for the direct irradiation is the absorbed perpendicular component of the solar irradiation incident on each sunny portion of surface.

To calculate the diffuse component of the solar irradiation the Hay model has been used. In this model we have modulated the dome diffuse radiation incident on each surface with the sky view factor for the surface, considering that in the urban canyon each surface only receives the dome radiation determined by this factor.

The reflected component of the solar irradiation has been calculated solving in each computational step of time the usual system that provides the short wave radiosities for each sunny and shaded area of the ventilated façade outer slab, the street floor and the opposite building façade, using the view factors between the different areas updated at each time step.

The long wave radiation exchange implies the temperatures of the different areas of the urban canyon and the sky that are updated at each step of time. For the apparent sky-temperature value we take from ASHRAE [2], the common correlation $T_{sky} = 0.0552\,T_{amb}^{1.5}$ where both temperatures are absolute and T_{amb} is the ambiance temperature. The long-wave radiant loss is expected to be inhibited due to the small sky view factor that urban canyons exhibit.

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In each step of time the radiative heat exchange between the surfaces delimiting the ventilated chamber are calculated too.

Equations governing the problem

The governing equations for the fluid are the conservation of mass, momentum and energy equations:

$$\begin{cases} Continuity: & \dfrac{\partial u}{\partial x}+\dfrac{\partial v}{\partial y} = 0 \\ Momentum: & \dfrac{\partial \vec{U}}{\partial t} + \vec{U}\cdot\nabla\,\vec{U} - \nabla\cdot\left(\nu\,\nabla\vec{U}\right) + \nabla p = \vec{b} \\ Energy: & \dfrac{\partial T}{\partial t} + \vec{U}\cdot\nabla\,T - \nabla\cdot(\alpha\,\nabla T) = 0 \end{cases}$$

where $\vec{U} = (u, v)$ is the velocity for the directions x and y, respectively; p the pressure; T the temperature; ν and α the cinematic viscosity and the thermal diffusivity of the air. Here $\vec{b} = \begin{pmatrix} 0 \\ -g\,\beta(T - T_{amb}) \end{pmatrix}$ represents the force of buoyancy due to natural convection, being g the gravitational acceleration and β the coefficient of thermal expansion.
For the fluid the condition of non-slip is imposed on all the surfaces of the ventilated façade and exterior soil. In the air inlet to the computational domain the speed and the temperature of the air is fixed. In the remaining borders, the values of speed and temperature of the air are the results of the calculation made.

Heat conduction through the outer slab and the inner wall is modeled by the equation

$$\frac{\partial T}{\partial t} - \nabla\cdot(\alpha\ \nabla T) = 0$$

Here the diffusivity coefficient α is variable taking the value corresponding to each material of the various layers which make the ventilated façade. This equation is closed with the boundary conditions given by the energy balance equation corresponding to each surface.

Numerical Simulation.

The set of equations describing the problem has been solved numerically in a two-dimensional domain that includes both urban canyon and a wide region outside it, in order to adequately simulate air flow. This domain has been meshed using triangular elements to perform a discretization of the problem by the Finite Element Method (FEM) to solve the Navier-Stokes thermodynamic equations. For this, the open source logicial FreeFem from French INRIA has been used. The equations of heat transfer through the inner wall and the outer layer have been solved by finite difference discretization.

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It has been considered a set of environmental conditions that tries to reproduce the most relevant ambiance features of the whole year in southern Spain. For this, we have used the data provided for Sevilla, Spain, by the Spanish State Meteorology Agency (AEMET).

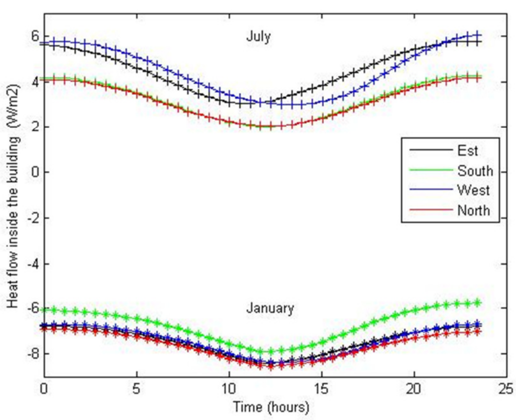
Studied façades features.

The height of the building is 30 mts and the considered external coating consists of ceramic slabs. The Spanish Technical Building Code [3] points for ventilated façades than the width of the chamber should be between 30 and $100\ mm$, and ventilation openings must have a total effective area at least equal to a $120\ cm^2$ for each $10\ m^2$ of facade between floors, 50% distributed between the upper and lower opening. Although some authors [4] point out that the optimum energy efficiency ventilated façade is achieved for a width camera about $15\ cm$, in this paper we stick to the values set by the Technical Code. The considered ventilated façade has a chamber width of 10 cm, and a height of 10 cm for the air vents placed between two adjacent floors whose height is considered to be 3 mts. This way the studied ventilated façade satifisfies the requirements specified in the Technical Code. Dimensions and thermophysical characteristics of the studied façades are listed in Table 1.

Layer	Description	Thickness (m)	Density (kg/m^3)	Specif.heat ($J/kg\ K$)	Conductivity ($W/m\,K$)
1(Ext.)	Ceramic slabs	.01	2800	1000	3.5
2	Air (ventilation duct)	0.1	1.184	1005	0.0255
3	Insulation	0.03	40	1674	0.029
4	Perforated bricks, lime mortar and cement	0.12	1800	1000	0.59
5 (Int.)	Plastering	0.01	1800	1000	0.90

Table 1. Thermophysical characteristics of the Ventilated Façade

For the external surface of the outer layer, an absorptivity value of solar radiation equal to 0.3 is considered. The same absorptivity is considered for the façade of the opposite building. For the street floor an absorptivity value of 0.5 is considered. The emissivity coefficient of the two surfaces of the external layer has been taken as 0.93 and for the inner wall surface facing the ventilated chamber, the emissivity coefficient has been taken equal to 0.75. These values are taken according to the technical specifications for the materials considered.



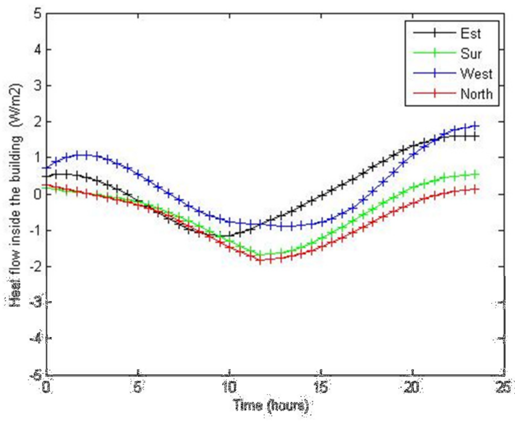


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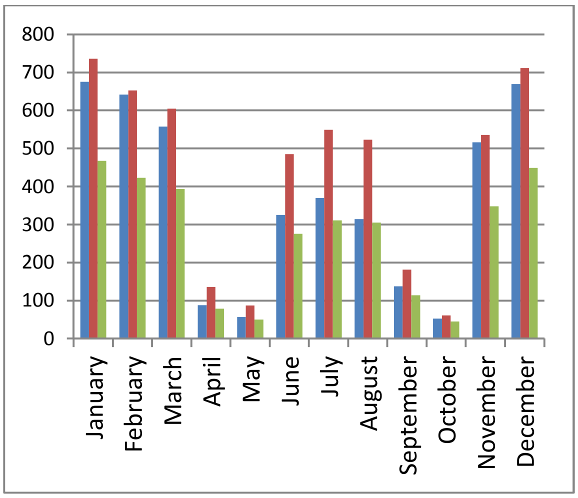
Fig2 Heat Flux for the FV in January and July *Fig.3 Heat Flux for the FV in May*

For the non ventilated façade (FNV) we have considered first a usual layout consisting of plastering, insulation, perforated bricks with the same characteristics and dimensions than the ventilated façace and a rough-coated of 0.15 mt. Also, we have considered a non ventilated façade (FNVRI) with an insulation of 0.06 mt. in order to increase the thermal isolation. The values of the emissivity and solar absortivity are considered the same that for the ventilated façade.

Results

In Figs. 2 and 3, whe show the hourly heat flow trough the ventilated façade for a day with average meteorological values of January, May and July, ir order to show the thermodynamic behavior of the ventilated façade in months of typical heat flow outward from. In these figures can be seen the lag of the heat flux due to the specific dynamic of the ventilated façade and the effect of thermal mass, respect the afternoon frequent higher temperatures in hot season in southern Spain. This lag can be exploited to match, hours of maximum heat flow with time of declining outdoor temperature, reduced solar irradiance and irradiative cooling night to lead to a better control of the heat flow into the building. Also we can observe the different behavior in these months for the East and West orientation, especially in summer, typical of the considered meridional latitude.



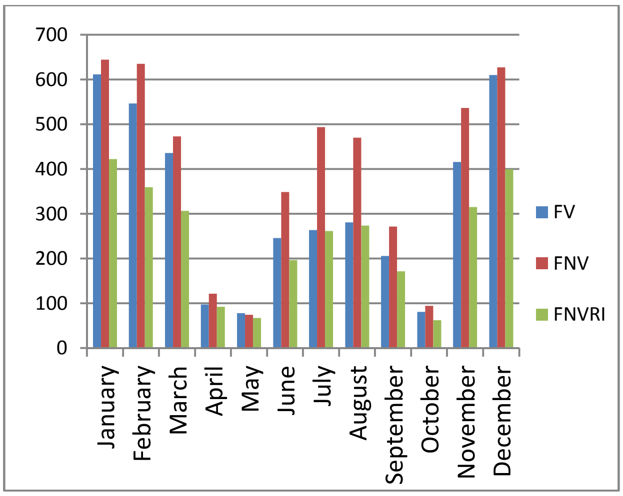


Fig.4 East Orientation: Daily Heat Flux (KiloJoules) *Fig.5 South Orientation: Daily Heat Flux (KiloJoules)*

In Figs. 4, 5,6 and 7, we show the heat flow inside the building for the ventilated façade (FV), the unventilated façade (FNV) and the unventilated one with reinforced insulation (FNVRI), for the orientations Est, South, West and North respectively, for a day with average m These values are the absolute value of the heat fluxes ir order to have an estimate of the total heat fluxe between the building and the environment, independently of its direction. We can observe that the best results correspond to the façade with reinforced insulation while the ventilated façade clearly improves the thermodynamic efficiency of the standard no ventilated

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façade but without actually giving such good results as the FNVRI one. This fact is also apparent in Fig. 8 where the annual total fluxes in kWh eteorological values of each month.

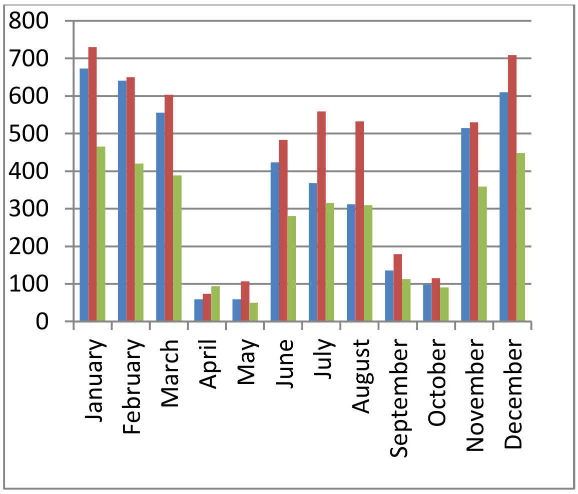

Fig.6 West Orientation: Daily Heat Flux (KiloJoules)

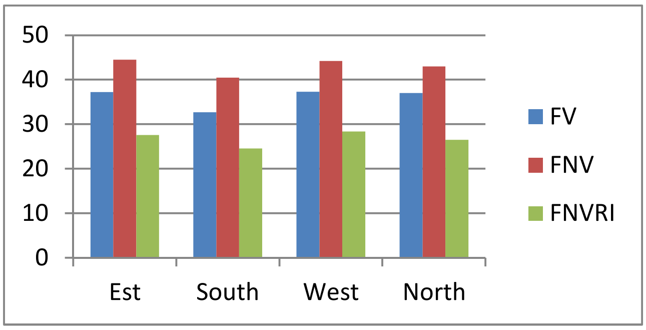

*Fig.8 **Whole year energy balance** for the FV, FNV and FNVRI facades in kWh.*

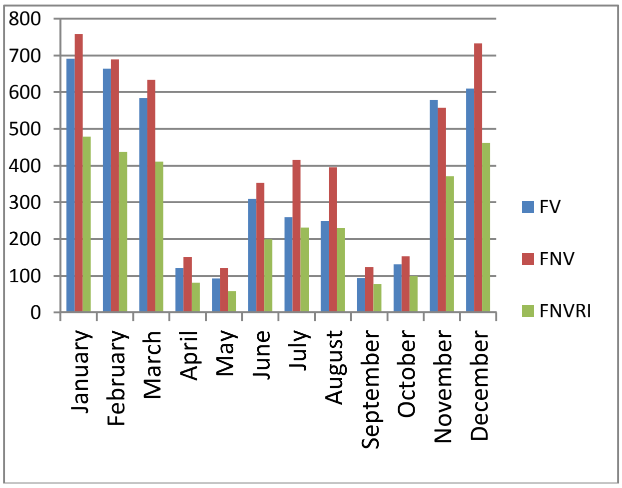

Fig.7 North Orientation: Daily Heat Flux (KiloJoules)

are showed for each orientation for the three considered façades

Conclusions

We can conclude the intermediate role that ventilated façade develops between the standard facade and facade with reinforced insulation. It is hard to find a single expliación for this fact, although the high conductivity of the outer layer of the ventilated façade used in the study can be decisive. Therefore we conclude that a careful selection of the outer layer is necessary to obtain good results if using ventilated facades in an urban context is considered. However it is important to highlight the good performance of the ventilated façade in summer, which it makes interesting its use for passive cooling in areas such as southern Spain, characterized by very high summer temperatures. In any case, economic factors in the cost of construction and possible energy savings should be estimated carefully before taking any decision on the constructive solution finally adopted in the specific context considered in this work.

References

[1] Sharples S. (1984). Full scale measurements of convective energy losses from exterior building surfaces. *Building and Environment*. **19**, 31-39.

[2] ASHRAE (1989). *Handbook*

[3] Código Técnico de la Edificación (Rd 314/2006 de 17 de Marzo).

[4] Ciampi M., Leccese F., Tuoni G. (2003). Ventilated façades energy performance in summer cooling of buildings. *Solar Energy*. **75**, 491-502.

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Floor-integrated HVAC-systems for zonal supply of multifunctional buildings

Speakers:
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Abstract: *Planning periods and utilization scopes, especially for commercial buildings, are getting shorter and future applications are harder to predict because of quickly changing social, demographic and economic conditions. That is why future sustainable buildings do not only need to be energy efficient, they also require a very high level of multifunctionality. They should provide modular flexibility as well as scalability and adaptability to the changing requirements. An innovative wide-span floor system enables an easy reconfiguration of building zones and the implementation of a modular floor-integrated heating-, ventilation- and air-conditioning-concept (HVAC). Here, the supply systems are particularly selected for the required supply situation of the separate building zones. Small and lightweight supply units with low power outputs have to be chosen to enable an independent supply for all possible zone types. Thereby, the combination of concrete core activation, underfloor ventilation system and heat pump represents a promising supply to meet the demand of different usage scenarios.*

Sustainable Building Design, HVAC, Modular Supply Systems, Multifunctional Buildings

Introduction

Construction and operation of buildings are responsible for approx. 40 % of the overall energy consumption and the resulting CO_2-emissions in the European Union [1]. Consequently, efficiency improvements in design, construction, utilization and operation have a huge impact on the energy demand during a buildings' lifecycle. Furthermore, even in industrialized countries the majority of contemporary buildings are used mono-functionally and do not take into account the dynamic requirements of today's user profiles (e.g. change of use, technological developments, demographic changes). This often leads to the necessity to demolish or substantially restructure such buildings long before they reach the end of their economic lifetime. In order to increase the usage efficiency and to exploit the buildings' full lifetime, adaptive structural systems with a high degree of flexibility have to be developed. Therefore, within an interdisciplinary project focusing on sustainable buildings of the future, a new and very adaptable approach to the construction of buildings and the design of supply systems is developed. Particularly, a concept for flexible floor slab integrated supply units is developed and its feasibility is analyzed.

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Within the performed analysis, necessary HVAC components and their required capacities for different usage scenarios (residential and offices) are determined. Based on this information, technically and economically feasible scenarios for supply component distribution within the floor slab structure are evaluated. Finally, a concept for standardized box-like exchangeable supply units is developed. These supply units require interoperability, scalability and common interfaces for control as well as connections with further facility infrastructure. Such a system could be dynamically reconfigured and adapted to changing technologies and requirements, thus enhancing usability as well as decreasing the lifecycle energy demand of the building.

Concept

With the aim of implementing a sustainable and multifunctional building concept in practice, an entirely flexible building structure with exchangeable wall and facade elements for new buildings is required. As shown in fig. 1, applying the same building area for different office or residential scenarios is possible. Matching this concept, modular supply units integrated in an innovative floor slab system allow dynamic adaptions to changing requirements.

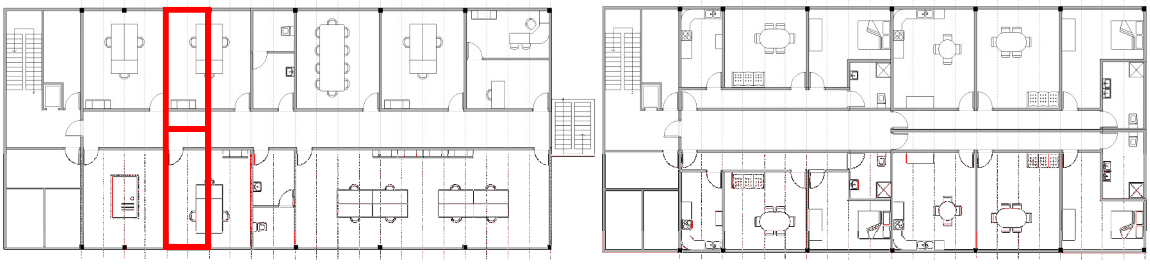

Fig. 1*: Exemplary floor plan of an office (left) and a residential building (right)*

Design principles for integrated floor slabs

The floor slabs need to provide high flexibility and adaptability in order to allow conversions and changes of use without significant modification of the building structure. Floor slabs do not only fulfill load-bearing and bracing functions; they create the separation between adjoining functional units and hence influence the planimetry, the installation of building services as well as physical properties of the building. In [2] a requirement profile for integrated floor slabs has been compiled that includes the most important factors in the fields of structural engineering, architecture, manufacturing, flexibility, fire protection, building physics, dismantling and recycling. One possibility to design multifunctional slab systems is to break up the conventional additive ceiling assembly (flooring, building services/ installations, suspended ceiling) and to dissolve the compact cross sections of conventional floor slabs into wide-span, multi-web structures. Essential properties of such integrated floor slab solutions are [3]:

- Complete and reversible integration of building services in the load-bearing structure with access from the top of the floor slab or through the facade to its installation cavity;
- Provision of bearing capacity reserves, large spans and waiving of intermediate supports in order to achieve maximum flexibility of use;
- High degree of prefabrication and use of detachable steel connections for ease of extension, short building times, components' reuse and building recycling;

- Continuous concrete slab for thermal efficiency and ensuring fire safety of the structure.

Development of an integrated floor slab system

Based on the design principles described above, an innovative integrated floor slab system has been developed. With spans of up to 16 m and width of 2.50 m (red line in fig. 1) as well as a bearable service load of 5 kN/m² the slab system offers a high degree of flexibility the zone design a usage (fig. 2). The detailed load bearing and deformation behavior of the floor-slab elements is presented in [4 - 6]. The slab system features an internal cavity of 0,5 m, which enables the complete integration of building services in the load-bearing structure (fig. 2).

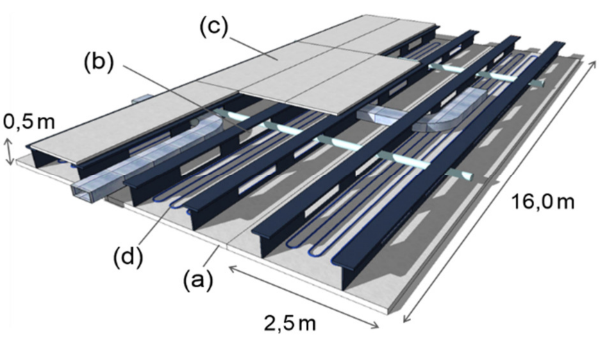

Fig. 2 *Integrated composite floor-slab system with (a) prestressed concrete slab, (b) large web openings, (c) removable cover panels, (d) integrated cooling lines*

Large web openings in the steel profiles allow a variable and adaptable routing even for ventilation ducts with large diameters (fig. 2 (b)). However, the demand for such web openings decreases with the level of supply system decentralization. Therefore structural efficiency of the floor slab can be further improved by reducing the size of the initially designed web openings. Ease of access to the supply systems within the floor and a convenient installation and maintenance of these components "from above" is achieved by the use of removable cover panels placed on top flanges of the steel profiles (fig. 2 (c)). Alternatively, installation and maintenance through flexible and exchangeable facade panels would be possible. This would reduce user impairment and increase maintenance flexibility. To improve the thermal comfort and energy efficiency of the enclosed living/working areas, the floor slab is equipped with integrated heating and cooling networks for thermal activation (fig. 2 (d)). The concrete slab thus determines the thermal performance of the floor slab system [7]. By its thickness of 10 cm the continuous slab additionally fulfills the fire safety requirements in the event of fire exposure from the underside. At the end of its lifetime the integrated slab system allows for an easy dismantling and reuse of single components as well as for a building recycling by means of detachable connections and joints. Instead of conventional material recycling, building recycling enables to employ the structure of a building over several cycles of use.

Demand Scenarios

The heating and cooling loads are calculated with SOLAR COMPUTER[1] for an exemplary building (fig. 1) in accordance with DIN EN 12831 [8] and VDI guideline 2078 [9]. The calculation of the air requirement is based on DIN 1946-6 [10] for dwellings and on EN 13779 [11] and EN 15251 [12] for commercial buildings. The results for specific rooms are

[1] The German software SOLAR COMPUTER enables calculations and design development for technical building systems, architecture and facility management.

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shown in tab. 1. These are approximate values based on typical configuration assumptions of the building and the rooms (i.e.: heat transfer coefficient, size, internal/external loads).

	Length	Width	Heating load		Cooling load		Air requirement	
	m	m	W/m²	kW	W/m²	kW	m³/h	1/h
Executive office	5.75	5.00	38.0	1.1	36.0	1.0	122.9	1.4
Group office	5.75	5.00	38.0	1.1	53.0	1.5	148.1	1.7
Open-plan office	5.75	15.00	38.0	3.3	59.0	5.1	419.0	1.6
Conference room	5.75	5.00	38.0	1.1	45.0	1.3	324.5	3.6
Server room	5.75	5.00	28.0	0.8	355.0	10.2	97.7	1.1
WC	5.75	2.50	38.0	0.5	14.0	0.2	61.4	1.4
Living-/bedroom	5.75	5.00	38.0	1.1	19.0	0.5	53.6	0.6
Kitchen	5.75	5.00	38.0	1.1	105.0	3.0	53.6	0.6
Bathroom	3.95	2.50	58.0	0.6	74.0	0.7	53.6	1.7

***Tab. 1**: Heating and cooling loads and air requirements of specific rooms*

Supply Scenario

The unconventional installation of the supply system makes the choice of adequate and efficient HVAC-components difficult. A compact (small and light) multifunctional plant construction is necessary. All supply units must be capable of covering the loads presented in tab. 1. Therefore, the baseload for heating and cooling operation is delivered through concrete core activations (CCA), however, the specific thermal demand of each zone needs to be provided additionally by radiator or ventilation systems. As shown in fig. 1, the CCA in each floor slab is divided lengthwise into two separately supplied zones and each room consists of at least one of these half-slabs. To prove the feasibility of the concept the suitability for floor integrated installation is analyzed for some of the most typical supply systems. Following, in tab. 2 and 3, main characteristics resulting from a detailed analysis are presented.

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	Characteristics	Size-critical components	Infrastructure connections
Thermal activation	Slow system, floor-ceiling connection	-	Water supply, return flow
CHP Fuel cell	Heat-controlled	Heat exchanger, inverter	Gas, supply air, exhaust gas, condensat removal
CHP Stirling engine	Heat-controlled	Stirling engine	Gas, exhaust gas
CHP Combustion engine	Heat-controlled	Combustion engine	Gas, supply air, exhaust air, condensat removal
Condensing boiler	-	-	Gas, supply air, exhaust gas, condensat removal
Heat pump	Air-water system, heating and cooling	Evaporator, fan	Supply air, exhaust air
Chilled water unit	Air-cooled	Heat exchanger	Water supply, return flow supply air, exhaust air
Ventilation system	Underfloor-installation	Heat exchanger	Water supply, return flow supply air, exhaust air

Tab. 2*: Characteristics and requirements of the analyzed supply systems*

	Heating capacity	Cooling capacity	Volume	Weight	Sound pressure level
	kW	kW	m³	kg	dB
CHP Fuel cell	0.6	-	0.25	120	30
CHP Stirling engine	3	-	0.21	110	45
CHP Combustion engine	2.5	-	0.43	100	46
Condensing boiler	0.9	-	0.11	33	42
Heat pump	2.8	2.7	0.14	55	35
Chilled water unit	-	1.4	0.13	46	48
Ventilation system	0.4	0.28	0.12	40	39
Thermal activation	33*	40*	entire slab	-	30

Tab. 3*: Technical details for the analyzed supply systems (minimal values of different manufacturers) [13]-[21]* * W/m²

Discussion

The particular loads of single half-slabs for the analyzed specific demand scenarios (tab. 1) are shown in fig. 3 together with the minimal capacities of the evaluated supply scenarios (from tab. 3). As it can be seen, most systems (except CHP fuel cell and condensing boiler) have to supply at least two or more half-slabs. Thus, adequately aggregated supply zones have to be built in order to guarantee an efficient supply concept; except for specific high requirement zones as conference or server rooms. To reduce the risk of failure and to extend

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the units' lifetime the number of clocking cycles should be minimized through the installation of buffer storages. Again, the aggregation of rooms with similar supply demands into larger supply zones can help to maximize the full load operation hours and minimize the required buffer storage capacities.

It has to be guaranteed that negative user impacts are avoided. In this context, according to DIN 4109 [22] the maximum sound pressure level of 30 dB in living- or bedrooms is acceptable. For systems with higher sound levels, compact insulation materials with low thicknesses can be installed, as presented in [23]. Moreover, solid-borne sound insulation is essential for all systems. Furthermore, sufficient air supply for ventilation purposes as well as for the supply of combustion processes, heat pumps and water chillers might be critical. If the aesthetic design of the building does not allow air supply openings in regular distances in the facade, the installation of a central air shaft within the floor slab could be realized. As seen in fig. 2b, the required cross-slab ducts can be easily incorporated in the floor slab concept.

The evaluation of the system size is complex since new individual plants, which are designed according to the available installation space, have to be developed. Still, it can be assumed that the required volumes stay constant when adapting the single components to the limited height of the floor.

Based on this fact, the CHP combustion engine (as the biggest plant, see tab. 3) needs nearly 1.5 m² of the floor space, expecting a plant height of 30 cm (leaving 20 cm for the floor panel covering, supply system mountings, ducts, insulation etc.).

As mentioned above, the floor slab system offers a bearable service load of 5 kN/m². Based on DIN EN 1991 [24], a minimum load of 2 kN/m² has to be guaranteed in office and residential buildings. Thus, the supply systems and the associated fixing materials, ducts and insulation should not exceed 3 kN/m². All the analyzed components match this requirement.

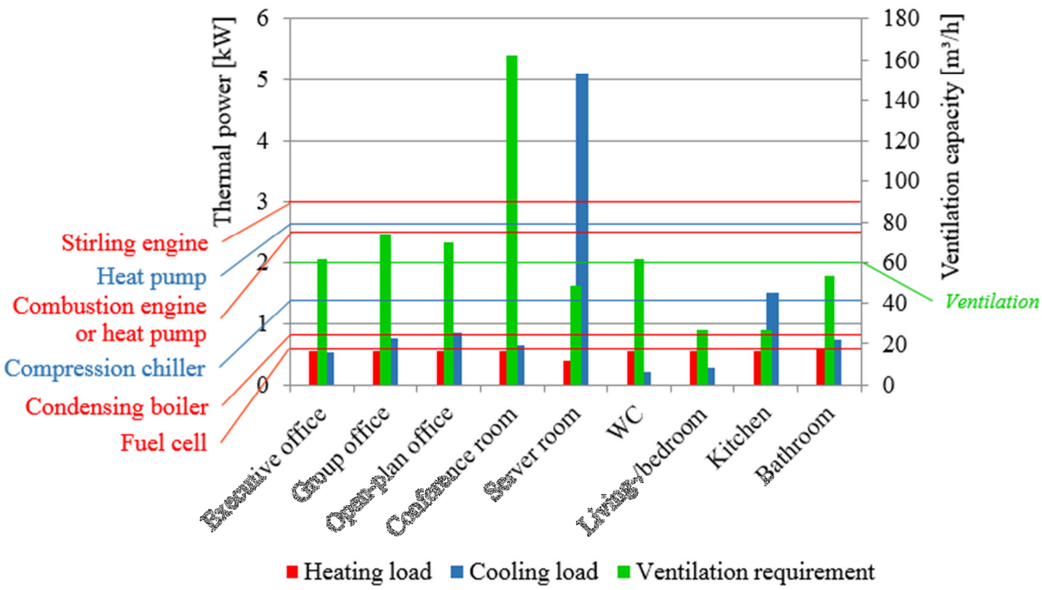

***Fig. 3**: Loads for a half slab of a specific room type and minimal capacities of the analyzed supply systems*

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Conclusion

Within the performed analysis, demand scenarios of typical office and residential buildings were defined and feasible supply scenarios were deduced. It was shown that the smallest possible supply units have to be chosen because of size- and weight-limitations and that constraints concerning possible numbers of clocking cycles have to be considered. Taking these boundary conditions into account, concrete core activation (supplying the heating and cooling baseload), an underfloor ventilation system and a heat pump (combined heating and cooling mode) turn out to be the best configuration option.

In conclusion, the described floor-integrated supply concept offers several advantages compared to conventional buildings. Modular floor slab systems consider dynamic requirements of different user profiles and make multi-functional building designs possible. Variation of use is possible as well as adaption to technological development. Demand and supply scenarios are optimally adjusted. Furthermore, the building's full range of lifetime is exploited and due to the easy replacement of inefficient components the lifecycle energy demand is decreased. Next, the dimensioning and operation performance of the supply systems have to be verified through dynamic simulations. Furthermore, an economic analysis of the presented approach in comparison to conventional building supply methods has to be performed.

References

[1] Spitalny, L. et al. (2014). Estimation of the economic addressable market of micro-CHP and heat pumps based on the status of the residential building sector in Germany. *Applied Thermal Engineering*

[2] Classen, M.; Gallwoszus, J.; Hegger, J.; et al.: Sustainability assessment of long span floor systems. Bauingenieur Volume: 89 Pages: 125-133, März 2014

[3] Dressen, T.; Classen, M.: Deformation of reinforced and prestressed concrete beams with large webopenings. Beton- und Stahlbetonbau, Vol. 108 (7) 2013, pp. 462-474

[4] Hegger, J. et al.: Multifunctional composite slab system with integrated building services. STAHLBAU Volume: 83, Juli 2014, S. 452–460

[5] Hegger, J.; Schaumann, P; Feldmann, M.: Entwicklung einer integrierten Verbunddecke für nachhaltige Stahlbauten, Stahlbau 82, Januar 2013, pp. 11-17

[6] Classen, M.; Gallwoszus, J.; Hegger, J.; et al.: Load-bearing behavior of an integrated composite floor system. Bauingenieur Vol. 89, (3) 2014, pp. 91-101

[7] Feldmann, M.; Pyschny, D.; Döring, B.: Investigation of thermal performance of the innovative multifunctional composite floor system. Bauingenieur Vol. 89, (3) 2014, pp. 116-124

[8] DIN EN 12831:2003-08, Heating systems in buildings – Calculation of the design heat load

[9] VDI-Guideline 2078:2012-08, Cooling Load Calculation of Air-conditioned Rooms

[10] DIN 1949-6:2009-05, Ventilation and air conditioning – Part 6: Ventilation for residential buildings

[11] DIN EN 13779:2007-09, Ventilation for non-residential buildings – Performance requirements for ventilation and room-conditioning systems

[12] DIN EN 15251:2012-12, Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics

[13] elcore. Elcore 2400. Available: online. http://www.elcore.com [accessed: 17.04.2014]
[15] SENERTEC. The Dachs. The Microcogeneration. Technical Data. Available: online. http://www.senertec.de/en/derdachs.html [accessed: 22.04.2014]
[16] Vaillant. Kraft-Wärme-Kopplung. ecoPOWER 1.0. Available: online. http://www.vaillant.de/ecopower [accessed: 22.04.2014]
[17] elco. THISION S. Available: online. http://www.elco.de/produkte/thision.html [accessed: 01.03.2014]
[18] Vaillant. Gas-fired wall hung condensing boilers. ecoTec plus. Available: online. http://www.vaillant.com [accessed: 15.05.2014]
[19] Vaillant. geoTHERM. VWL 35/4. Installations- und Wartungsanleitung. Available: online. http://www.vaillant.de [accessed: 15.05.2014]
[20] Rehsler Kühlsysteme. TAE evo. Available: online. http://www.rehsler-kuehlsysteme.de [accessed: 21.05.2014]
[21] TROX Technik. Air-Water Systems. Decentralised Ventilation 2014. Available: online. http://www.trox.de/en [accessed: 24.03.2014]
[22] DIN 4109:2012-08, Sound insulation in buildings; requirements and verifications
[23] WOLF Bavaria. Professional Sound Insulation. Available: online. http://www.wolf-bavaria.eu [accessed: 05.05.2014]
[24] DIN EN 1991-1-1/NA:2010-12, National Annex – Part 1-1: General actions – Densities, self-weight, imposed loads for buildings

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Session 36:

Do we know all the benefits of sustainable management?

Chairperson:

Gálvez, Miguel Angel

Doctor Arquitecto. Profesor Titular Interino. Escuela Técnica Superior Arquitectura Madrid, UPM

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Festivals as laboratories: Developing new temporary housing

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Abstract: *Many music and culture festivals are held around Europe each year, which attracts a very large number of people for longer or shorter periods. Although temporary in nature, these festivals generate masses of solid waste and sewage, consumes high amounts of electricity etc. The environmental effects do not go unnoticed, but dealing with them is challenging for both organisers and guests. This paper is based on a case study of the Roskilde Festival using a range of methods and data like statistics, site visits, observations, interviews as well as photo and video documentation. This paper will 1) analyse experiences gained from experiments with new types of temporary housing at the Roskilde Festival 2013, 2) suggest a number of initiatives to make temporary events more sustainable, and 3) discuss what lessons can be learned from temporary events with regard to fundamental taken-for-granted assumptions on housing and living in society in general.*

Keywords: Innovation, clients, users, housing, events, waste

Introduction

A society based on a 'green' economy requires the development of new competitive technologies and solutions that inter alia increase recycling of waste and reduce incineration of waste in particular with regard to plastics and metals (Regeringen 2013). The Danish government has recently launched an ambitious resources strategy for waste management (Regeringen 2013) in response to the 7th Environment Action Programme by the European Union (2013). Over the past 20 years an increasing amount of waste in Danmark has been recycled or incinerated, while the percentage of waste for landfill has dropped low. Denmark is not on par with other EU Member States recycling the most, but is ranked 8 with regard to recycling waste collected by municipalities with a recycling rate of 42 %. The incineration rate of 55 % is the highest among EU Member States (see Figure 1).

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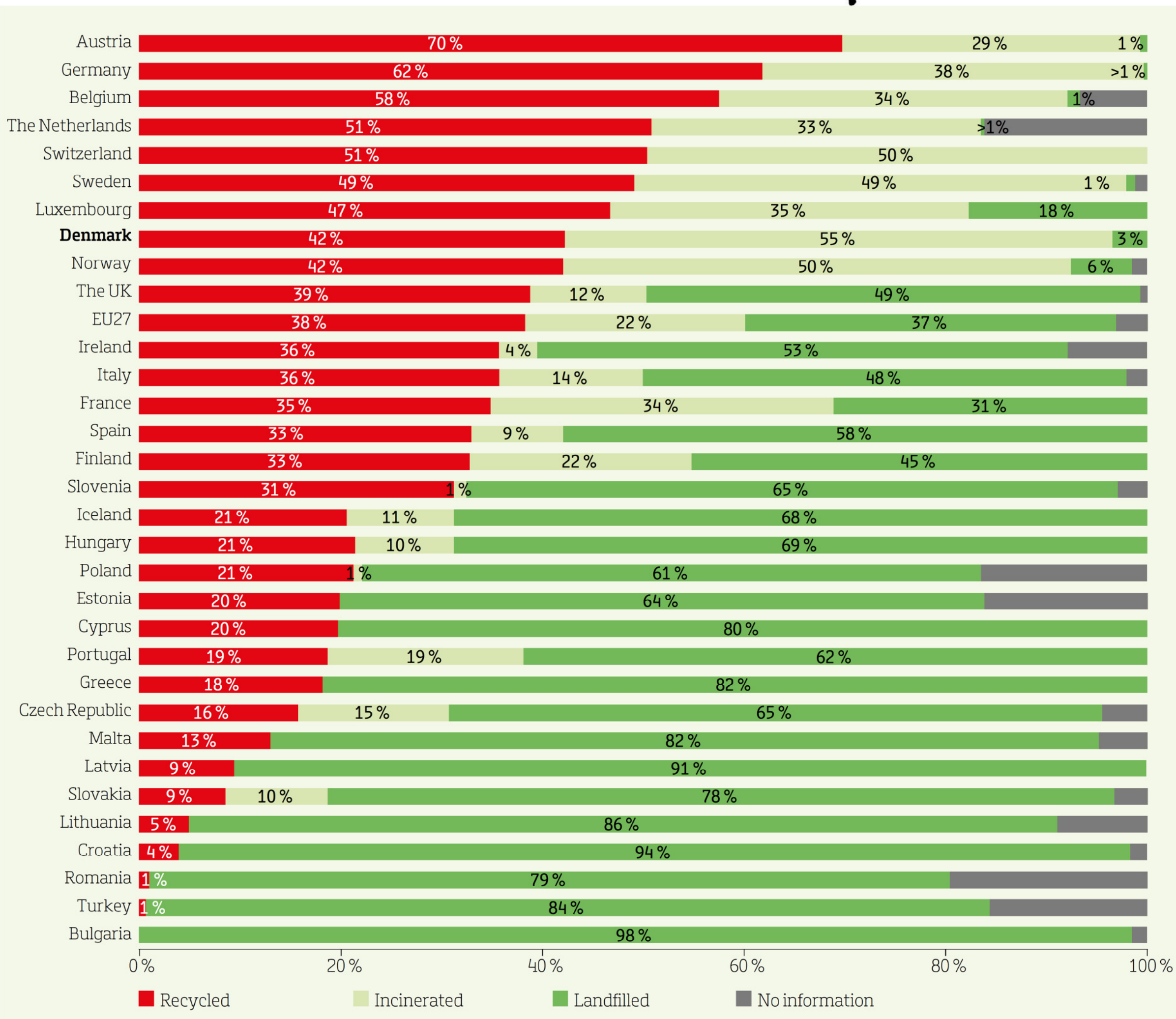

Figure 1. Waste treatment in European countries. Source: (Regeringen 2013: 21).

According to the Danish governmental statistics on waste (Miljøstyrelsen 2013 and 2014), private households account for more than 1/4 of the total amount of waste generated annually. Nowhere is this more visible than at the end of the Roskilde Festival – the largest music and culture festival in northern Europe. When the festival is over in early July, the camping area is floating with tons of waste like abandoned tents, chairs and pavillons along with various types of household waste like food, cans and bottles as well as hazardous waste like batteries and car batteries (see Figure 2).

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Figure 2. Waste at camping area after the Roskilde Festival 2013. Photo: Kim Haugbølle.

Many similar events are taking place around Europe each year, which attracts a very large number of people for longer or shorter periods. Although temporary in nature, these temporary events generate tons of waste including precious metals and plastics, consume high amounts of electricity, produce huge volumes of sewage often under rather uncontrollable conditions etc. The environmental effects do not go unnoticed, but dealing with them is challenging for both organisers and guests.

Due to the temporary nature of these events a range of temporary constructions are needed to provide accommodation, sanitary facilities, food stalls, stages etc., but these are seldom given the attention regarding sustainability and resource-efficiency as permanent structures. While stage building is typically done by professionals and/or skilled volunteers, accommodation is mostly provided by the guests themselves.

The most widespread form of temporary accommodation is the tent. Today, various types of tents are used for festivals, but tents are also used as temporary housing for relief work in disaster areas and refugee camps for the around 51 million forcibly displaced worldwide (UNHCR 2014). Although these types of tents are typically of different quality and size, they share a range of the same challenges as tents used for festival purposes – durability, efficiency and purposefulness. Thus, the development of new types of temporary housing is not only relevant for festivals, but holds the potential of being applicable in a range of other settings like disaster areas, refugee camps and military missions abroad.

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During the 2013 Roskilde Festival several new examples of temporary housing was developed and tested to challenge the dominant form of temporary housing – the tent. These experiments took place in Dream City – a part of the camping area assigned by the festival to experiments by festival guests.

This paper will 1) analyse experiences obtained from experiments with temporary housing at the Roskilde Festival, 2) suggest a number of initiatives to make temporary events like festivals more sustainable, and 3) discuss what lessons can be learned from temporary events with regard to fundamental taken-for-granted assumptions on housing and living in society in general.

Methodology

Rather than reproducing the all too familiar complaints about the temporary nature of construction activities (and many other activities) as a hindrance to sustainable innovation (see e.g. Häkkinen & Bellonia 2011 and Gann & Salter 2000), this study will take the opposite position. Indeed, this study will take temporality as a *positive* starting point for asking how sustainable built environments can be advanced. However, our knowledge on how temporality matters in the built environment is sparse except for a few studies e.g. on management and governance in project-based organisations (Clegg et al. 2002; Bresnen et al. 2004) and spatial agency in architecture and urban planning (Awan et al. 2011).

Temporary events like the Roskilde Festival provide an excellent laboratory and accelerated test bed for developing and testing new technologies and solutions in close collaboration between organisers, guests and suppliers. Based on a sociotechnical approach (see e.g. Bijker & Law 1992; Jasanoff et al. 1995), the objective is to establish a scientific knowledge base on how temporality shapes sustainable built environments with regard to four interrelated themes of constructions, sociotechnical change, governance and business models.

The study is based on a case study design. Festivals represent an extreme case that shed light not only on temporary constructions as such but also on the fundamental workings of the built environment in general (Flyvbjerg 1991, Yin 2009). Festivals mirror the built environment as it is typically known, but it also transcends common taken-for-granted assumptions about the built environment. Despite the temporary nature of festivals, the guests still need many of the same functions as in everyday life, such as being able to shower, sleep, toileting, eating, etc. Due to the festival's temporary nature this happens with means other than those normally applied. This makes the festival a particularly appropriate platform for the study of how residents perceive and use their "home", and the interaction between "city" structures and residents' agency under construction, use and dismantling of the city. As such temporary events like festivals offer an excellent opportunity to look into and to experiment with new sustainable solutions in an accelerated context, which may generate scientific insights applicable in the built environment generally.

Data collection took place before, during and after the 2013 festival by four researchers with complementary expertise within architectural design, innovation, constructions and fire and

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safety. Data was collected through a combination of methods and sources. Statistics gathered by the festival organisers at previous festivals included general business information on the festival, waste statistics and profiles of the guests. These statistical data were supplemented with participant observation during the festival, interviews with festival guests and site visits to the festival as well as the development labs of Rockwool. Data was documented using written notes, several hundreds of photos, tape recordings and approximately 300 GB of video recordings (Kvale & Brinkmann 2009, Kristiansen & Krogstrup 1999).

Case: Roskilde Festival

Roskilde Festival is the largest North European culture and music festival and has existed since 1971. The festival is organised by the Roskilde Festival Charity Society. The purpose of the society is to support initiatives benefitting children and young people and to support humanitarian and cultural work. The society's work is independent of party politics and has no geographical borders. Roskilde Festival is a non-profit organisation with about 50 full-time employees and some 800 volunteers who typically spends one day per week all year round working on specific tasks related to the festival. During the festival itself the number of volunteers increases to about 32,000. These volunteers staff the festival stalls, build stages, provide camping security etc. Most volunteers are from cultural organisations and sports associations located around the city of Roskilde, but some 20 % of the food stalls are run by professionals like the famous chef Claus Meyer. Besides the volunteers a number of professionals are working at the festival.

The Roskilde Festival is hosting some 130,000 people. This makes Roskilde Festival the fourth-largest “city” in Denmark for nine days. Although the festival holds strong values related to sustainability, the very temporality of the event, the state-of-mind of party-minded festival guests, the buy-and-through-away mentality fuelled by easy access to very cheap tents, chairs and pavilions etc. poses significant challenges to the realisation of the sustainability ideals. In 2012, the festival resulted in 1,850 tons of waste that was mostly incinerated at the nearby waste treatment plant. The water consumption equalled that of the permanent city of Roskilde, and the power supply was close to its maximum load due to the electricity needed for cooling storage of food rather than for electricity to the stages.

The most common form of housing at a festival is a tent. The tent is available in a variety of forms such as the villa tent, the dome tent and the pop-up tent. The quality of tents are very diverse and ranges from expensive trekking tents costing several thousand DKK (>EUR500) to cheap festival tents sold down to DKK250 (EUR35) in stores, hardware stores, etc. Especially the dome tent in the cheap version dominates the camping areas on e.g. Roskilde Festival. The tent has a number of advantages such as light weight, easy to carry, inexpensive, flexible, simple to set up, etc. The tent has a number of drawbacks such as weak climate control (temperature and humidity), low level of security, no noise insulation, no privacy, etc. A large part of these tents is abandonned at the end of the festival and ends up as waste being incinerated.

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There are other types of housing solutions at the Roskilde Festival. Some guests choose to accommodate themselves in the few permanent hotels in and around the city of Roskilde, bed-and-breakfasts (either permanent or pop-ups for the occasion), privately at friends and family, nearby summer cottages or at permanent campsites nearby. In addition to the festival campsite, the Roskilde Festival also offer to accommodate guests in other ways:

- Get A Tent (for those who want to arrive to a pitched tent).
- Get A Place (for those who want to prebook a dedicated area for their camp).
- Caravan Camping (for those who want to bring their own caravan).
- MC Camping (for motorcyclists).
- Sleep-in Busses (for those arriving by their own bus).

Finally, there are camping areas for employees, performers, etc. including employee camping at a close-by sports facility, in classrooms at the nearby Roskilde Technical School or in the backstage area between the two largest scenes named Orange and Arena.

In line with an ordinary city the various camping areas or “neighbourhoods” holds different profiles. Some of these are organised by the festival such as the camping areas Clean & Silent and Dream City. There are also non-intentional differences between the camping areas. The closer you get to the enclosed space of the music stages, the closer the tents will be pitched. The camping areas will be more densely populated, more noisy, more waste will be dumped between the tents and the unmistakeable smell of urine will be prevalent.

A variety of other types of accommodation facilities can be found at other festivals. Another large-scale Danish music festival – SMUKFEST – extensively applies the concept of “Hotelt” (contraction of the two Danish words “hotel” meaning hotel and “telt” meaning tent). A Hotelt is a pitched tent booked in the same manner as a hotel room. The tents are erected in advance of the festival and provided with a padlock. They are located closest to the stages whereas the area for own tents are located farther away. There are also various other solutions such as “campers” with built-in power supply and containers shaped as over-sized beer cans with a range of additional services like free newspapers, refrigerators, daily supplies of cold beer etc. At the English festival Glastonbury, the podpads – a small house made of plywood – are applied along with Mongolian-style yurts and teepees.

In recent years, Roskilde Festival has dedicated part of the camping area to Dream City – an experimental area where the festival guests within the boundaries of the fire and safety regulations have extended freedom to design the area to their own needs and wishes up to 100 days before the festival starts. In 2013, this led to the establishment of among others a post office, a town hall, a race track for mountain-bikes and a graveyard for dead rock’n’roll guitarists. The Danish artist Thomas Dambo developed a “hotel” called Happy Mountain consisting of a number of small 2 x 1 x 1 m plywood boxes stacked within a geometry of 8 x 12 x 5 m. The idea was to ask the guest to build their own hotel box and to reuse the boxes at the following festivals. However, the boxes turned out not to be waterproof and mould started growing in some of the boxes.

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In 2013, a number of new housing solutions was tested at Roskilde Festival (see Figure 3).

Figure 3. Examples of alternative temporary housing. Photos: Kim Haugbølle.

Some years back the festival developed a two-person accommodation in large concrete tubes. These were relocated to Dream City in 2013. Clearly the relocation proved rather cumbersome due to the weight of the concrete tubes. The round shape of the tubes also made some festival wags try to roll over the tubes, which was prevented by infusing a sort of foundation. While this solution have promotional value it is not a solution that is expected to be widely used.

Dream City also included three large white tents of 20 m^2 called DOMO that was designed as a modular emergency shelter system for crisis by the newly established design firm **more**thanshelters GmbH. They had won an innovation competition for new types of housing held in 2012 by the Roskilde Festival. According to interviews with the occupants of the DOMO, the tent provided a comfortable temperature compared to typical tents due to the large indoor air volume. However, the assembly proved time consuming and technically challenging to the unskilled guests occupying the DOMO, and it was probably only possible to pitch the tent because the main designer was present at the festival.

The new housing solutions also included two types of experimental housing developed by Rockwool called the Cube and the Dome. Three copies of each was erected in Dream City and was inhabited by festival guests during the festival. The testing of the various new types of housing provided a number of experiences on the importance of different functional properties of new temporary housing. The mounting of the two solutions took around 30 minutes each for two skilled labourers and required the use of hand tools. The grid steel structure of the Dome proved cumbersome to erect and did not provide sufficient stability. The residents of the tested solutions were generally pleased with the Rockwool solutions because they gave a much better indoor climate control (temperature and humidity), reduced noise, and provided greater privacy for the residents.

Since the Roskilde Festival 2013 the lessons learned have been digested. During the winter and spring 2014 Rockwool has continued developing the Dome and Cube into a combined solution to address some of the weaknesses experienced at the 2013 festival. The major improvements include:

- Essentially the new version called Rockwool Shelter is based on the octagonal design of the Dome and the structural system and choice of materials from the Cube.

- A new special roof cover has been designed.
- An eaves of ca. 1.5 m^2 is added to provide sunshading and protection against rain in front of the Shelter.
- The unstable door and lock was replaced with a double-wing door made of the integrated steel/Rockwool panels and a padlock.

At the upcoming festival 2014, 54 examples of the new Rockwool Shelter will be tested in the Get A Tent area. The Rockwool Shelter has a size of around 4 m^2 and is intended for two persons. Despite the additional price of DKK2,500 (EUR335) all 54 Rockwool Shelters were sold out shortly after the announcement. At the upcoming festival, the research team in collaboration with the R&D department at Rockwool and the festival organisers will observe, interview and distribute a questionnaire to the occupants of the 54 Rockwool Shelters.

Conclusion

First, this study has generated new scientific insights that may be instrumental in developing new technologies and processes, which can reduce the environmental impacts of temporary events, improve users' satisfaction of temporary housing, and improve the organisation, planning, execution and dismantling of temporary events.

Second, the results are expected to reduce the environmental impacts related to the excessive amounts of waste from abandoned tents that are being left behind at temporary events and often simply being incinerated. The improvements may take place through 1) new design of temporary structures with new types of materials, 2) increased reuse of temporary housing solutions from one event to another, and 3) improved recycling of the actual materials being used.

Third, this study and its continuation in the coming years will generate new insights into the hitherto rather neglected area of temporary constructions. These new insights are believed to lead to a critical review of existing public regulation or lack hereof of temporary constructions for example with respect to waste minimisation and safety including fire hazards.

In conclusion, the development and testing of prototypes of temporary housing at consecutive festivals in the coming years holds the potential of moving into a fully commercially available product and business model, which can lead to new business opportunities. The expected outcome will not only satisfy the immediate temporary housing needs of festival guests, but the lessons learned may very well be applicable to the commercially far more interesting markets of emergency shelters, military missions abroad, temporary housing/offices for construction professionals and temporary resettlement of dwelling residents.

References

Awan, N, Schneider, T. & Till, J. (2011). *Spatial agency. Other ways of doing architecture.* Abingdon, UK: Routledge.

Bijker, W. E. & Law, J. (eds. 1992). *Shaping Technology/Building Society – Studies in Sociotechnical Change.* Cambridge, Massachusetts: MIT Press.

Bresnen, M., Goussevskaia, A. & Swan, J. (2004). Embedding New Management Knowledge in Project-Based Organizations, *Organization Studies*, 25 (9): 1535-1555.

Clegg, S. R., Pitsis, T. S., Rura-Polley, T & Marosszeky, M. (2002) Governmentality Matters: Designing an Alliance Culture of Inter-Organizational Collaboration for Managing Projects. *Organization Studies*, 23 (3): 317-37.

European Union (2013). DECISION No 1386/2013/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 20 November 2013 on a General Union Environment Action Programme to 2020 'Living well, within the limits of our planet', *Official Journal of the European Union*, L 354: 171-200.

Flyvbjerg, B. (1991). *Rationalitet og magt. Bind 1. Det konkretes videnskab*. København: Akademisk Forlag.

Gann, D. M. & Salter, A. J. (2000). Innovation in project-based, service-enhanced firms: The construction of complex products and systems, *Research Policy*, 29 (7-8): 955-972.

Häkkinen, T. & Bellonia, K. (2011). Barriers and drivers for sustainable building, *Building Research & Information*, 39 (3): 239-255.

Jasanoff, S., Markle, G. E., Peterson, J. C. & Pinch, T. (eds. 1995). *Handbook of Science and Technology Studies.* Thousand Oaks, California: SAGE Publications Inc.

Kristiansen, S. & Krogstrup, H. (1999). *Deltagerobservation. Introduktion til en samfundsvidenskabelig metode.* København: Hans Reitzels Forlag.

Kvale, S. & Brinkmann, S. (2009). *InterView. Introduktion til et håndværk.* København: Hans Reitzels Forlag.

Miljøstyrelsen (2013). *Affaldsstatistik 2011.* København: Miljøstyrelsen.

Miljøstyrelsen (2014). *Danmark uden affald. Ressourceplan for affaldshåndtering 2013-2018. Vejledning fra Miljøstyrelsen, nr. 4, 2014.* København: Miljøstyrelsen.

Regeringen (2013). *Denmark without waste. Recycle more – incinerate less.* København: Miljøministeriet.

UNHCR (2014). *UNHCR Global Trends 2013.* Geneva, Schwitzerland: United Nations High Commissioner for Refugees.

Yin, R. (2009). *Case Study Research. Design and Methods. Fourth Edition.* Thousand Oaks, California; London, New Delhi & Singapore: SAGE. Applied Social Research Methods Series – Volume 5.

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Active+ Stadia: Guidelines and Indicators for Sustainability and Plus-Energy Mega-Event-Buildings

Abstract:

Over the past years, organisation committees of mega-events like the Olympic Games or European and World Football Championships, have been demanding more and more for the evaluation of the sustainability performance of their venues. These assessments have been made with different instruments and a comparison of the sustainability performance between them is not yet possible. Therefore, the abstract will show a common and new set of criteria, indicators and benchmarks to assess the sustainability performance of sports architecture whichincludes next to the ecological criteria, social and economic aspects as well, covering the whole life-cycle of the venues. Next to these aspects the abstract will provide guidelines for plus-energy and carbon-neutral venues and their interaction with the infrastructure of the city districts as an energy provider and an energy storage facility.

Keywords: Sustainable mega-event venues, planning instruments, assessment methods, plus-energy concepts

Introduction

Mega-Events, like Olympic Games or World and European Football Championships require high investments in the infrastructure, sports facilities and the accommodation of the athletes and have an enormous ecological and social impact on host cities as well. To implement sustainable concepts in Olympic Games or in Football World and European Championships, the IOC (International Olympic Committee) and also the FIFA/ UEFA (International Football Association Board/ Federal International Football Association/ Union of European Football Associations) have in recent years started to demand for sustainability impact assessments for the host venues.

Different sustainable planning concepts and sustainability assessment methods have been adopted by the host cities and organisation teams as well. Examples are the venues of the Vancouver 2010 Winter Olympic Games (LEED Canada), the London 2012 Olympic Games (BREEAM) and for the Stadia of the Football World Cup 2014 in Brasilia (LEED U.S.). However, this process is just at the beginning and the implementation of sustainability aspects into mega-event venues is still on an early stage. Furthermore, criteria for social or economic matters and benchmarks for plus-energy or carbon-neutral aspects are still missing.

Therefore, this paperwill show a new set of criteria, indicators and benchmarks developed to assess the sustainability performance of sports architecture that includes next to ecological criteria, social and economical aspects as well. Next to these topics the paper will provide concepts for plus-energy and carbon-neutral venues and their interaction with the infrastructure of the city districts as an energy supplier and an energy storage facility.

The abstract is based on the results of the dissertation “Sustainability of Olympic Venues” that was published in 2010 [1], on the outcomes of the research project “Guidelines for Sustainable Venues of Mega-Events” that was supported by the BMWi (Federal Ministry for Economics and Technics) from 2012 to 2013 [2] and the research project “Smart Stadia: Development of a planning instrument for CO2-neutral and energy efficiency of stadia and their interaction with the surrounding neighbourhoods" that have started in 2014. During these studies, an analyses of the concepts and an impact assessments for recent Olympic Games and Football Championships have been done. Also sustainability and energy reports of NGOs, like UNEP, Greenpeace or WWF have been integrated into the analyses, as well as the sustainability guidelines and regulations of the IOC and the FIFA/ UEFA.

Until now, there is no generally agreed upon definition for mega-event buildings. Based on the studies of Eßig 2012 buildings for large events could be defined as follows [2] [3]:

"Mega-event buildings are buildings that are built or redeveloped temporarily or permanently for a time limited major event and that be checked by the rights holder or organizing committee for their applicability After the mega-event they will have the same, similar or different re-use."

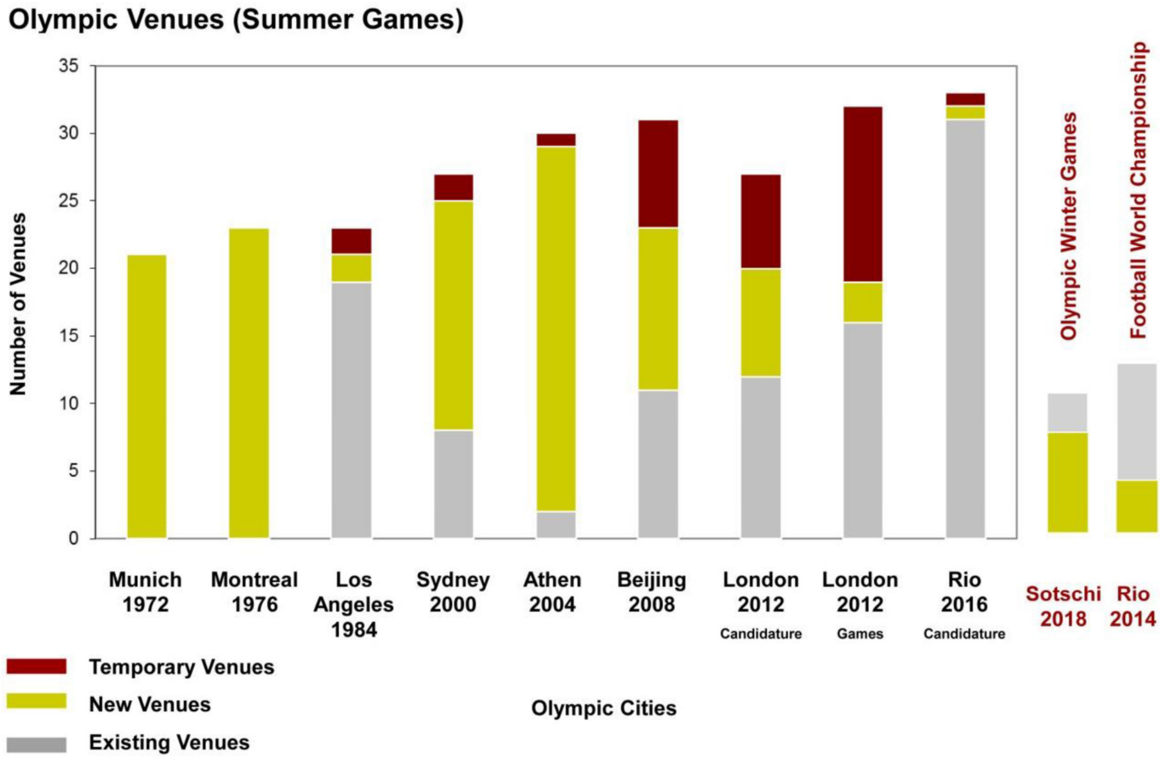

Figure 1: *Number of mega-event buildings since 1972 [1]*

Increasing Number of Mega-Event-Buildings

Nowadays, the number of mega-event buildings is increasing from event to event and next to temporary and existing sport facilities, new built-up stadia and halls are the main construction activities.For Summer Olympic Games, 25 to 30 venues are used to host the competitions, and for the Winter Olympic Games the number is between 15 and 20 sports facilities. For football World Cups an average of 8 to 12 stadia are required (see fig.1). However, the number of venues, depends on the host countries and cities (e.g. 2010 FIFA World Cup South Africa: 10 stadia, FIFA World Cup 2006 Germany: 12 stadia) [1].

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Environmental and Sustainable Guidelines of Non-Profit-Organisations (NGO), Sport Federations and Organising Committees

To implement sustainable concepts in Olympic Games or in Football World and European Championships, the IOC (International Olympic Committee) and also the FIFA/ UEFA (Federal International Football Association/ Union of European Football Associations) have started recently to demand for sustainability impact assessments for the host venues. However, the intent of these guidelines and projects is focused more on the environmental friendly management of the events, rather than on the sustainble planning, construction and operation of the venues. For mega-events in general a number of sustainbility guidelines have been developed, such as the guideline "Green Champion - Guide for Large Sporting Events" which has been developed by the German Olympic Sports Confederation (DOSB) together with the Federal Ministry of Environment (BMU) in 2009. For European and World Football Championships the project “Green Goal” has been proposed for the World Cup 2006 in Germany. The concept was later adapted at the Football World Cup 2010 in South Africa, as well at the Women World Cup 2011 in Germany [5].

While football associations, like FIFA or UEFA have launched the implementation of environmental topics just for a few years, the IOC has started to support the Host Cities to implement environmental friendly measures since the early nineties. Some of the important steps made in this directionare, the announcement of the environment as the third dimension of the Olympism in 1994, the implementation of an environmental chapter in the Olympic Charter and the foundation of the Sports and Environment Commission in 1996. In addition, numerous voluntary guidelines, such as the Olympic Movements Agenda 21, the Manual on Sport and Environment and the IOC Guide on Sport and Environment have been established. This development is supported by further mandatory IOC tools, the so-called “Five Pillars” of the Olympic Games Management, which starts from the Applicant and Candidature Procedure and Questionnaire to the Audit and Masterplan [1].

National and International Assessment Methods for Sustainable Venues of Large Sport Events

While both FIFA and UEFA are requiring that an environmental assessment of their venues based on the American label LEED is to be done, the IOC is asking in its candidature procedure for national sustainability evaluations. This development goes back to the Olympic Games 2000 of Sydney, where benchmarks have been launched for the first time to assess the ecological aspects of the venues . The national Australian assessment methods Green Star (Green Building Council Australia – GBCA) and NABERS (National Australian Built Environment Rating System, Australian Government) have been developed on the basis of the Olympic indicators [1]. The organising committees of the Olympic Winter Games of Vancouver 2010 (VANOC) and the London Summer Games of 2012 have certified their new and existing competition venues and non-competition facilities by applying existing national assessment schemes to build and operate Games facilities, that would ensure a minimal environmental footprint. Vancouver, for instance, has used the North-American system LEED Canada (Leadership in Energy and Environmental Design) to assess its Olympic sports facilities. For the London Games 2012 the label “BREEAM for Olympic Park and Venues” was developed by BRE (Building Research Establishment) within the national sustainability method BREEAM (BRE Environmental Assessment Method) to assure the ecological implementation of the Olympic venues [5]. For the Olympic venues of the Beijing 2008 Games, the Chinese Ministry of Construction (MoC) and the Ministry of Science and Technology (MoST) have especially developed the Green Olympic Building Assessment System

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(GOBAS), which is based on the Japanese assessment method CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) and the North-American LEED system. For the Olympic Winter Games of Turin 2006, the Turin media village was assessed by means of GBTool, which provided the basis for the current national assessment method PROTOCOLLO ITACA. The example of the Winter Olympic Games of Sochi 2014, however, shows that the use of assessment methods for Olympic venues has not yet been enforced on all host countries. First approaches to assess the Olympic venues of Sochi, has been mentioned in the Bid Book (application form), but concrete implementations of the sustainability assessment system are not visible one year before the Games. At the moment the development of a BREEAM Russia version to assess the venues is under discussion [4] [5].

Considering that the IOC is only demanding for assessing the sustainability performance of the facilities, but not giving out common mandatory indicators and benchmarks, the host cities have fulfilled this requirement with different assessment tools in the last year. Due to these diverse instruments, it is not possible to compare the evaluation results of the venues as they have different significances according to environmental, economic and social aspects and do not take into account, the entire life cycle of the sport venues (Olympic legacy).

Criteria and Indicators for the Sustainability Performance of Mega-Event Venues

At the moment a comparison of the sustainability performance of mega-event buildings is not yet possible. In most cases just the ecological, the energy efficiency aspects and the use of the buildings during the mega-event are analysed. Social, economic, technical, functional, process and site orientated criteria, as well as the re-use of the buildings after the event have been so far not addressed. Therefore the paper shows a new set of common criteria, indicators and benchmarks for the sustainability performance of mega-event sports architecture.

The structure of the indicator catalogue is based on the results of the EU project "OPEN HOUSE" (www.openhouse-fp7.eu). The main goal of the OPEN HOUSE, which was initiated in the seventh research framework programme, was to develop a European methodology for assessing the sustainability performance of buildings (time period: February 2010 to August 2013) [6]. Next to the OPEN HOUSE six pillars model

- Ecological Quality
- Social/ functional Quality
- Economic Quality
- Technical Quality
- Technical Characteristics
- Process Quality
- and the Site

Special indicators for mega-events have to be considered as well. After analysing the voluntary and mandatory guidelines of the IOC and the FIFA/ UEFA and the sustainability reports of the NGOs, like UNEP, Greenpeace or WWF and discussions with mega-event experts, the new category

- Quality of Mega-Event Venues was added [2].

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Figure 2: *Sustainability categories for mega-event buildings based on OPEN HOUSE* [2]

Based on the results of the project a catalogue with 63 indicators for sustainable mega-event buildings have been developed [1] [2]. In summary 25 core goals for sustainable venues could be derived from this catalogue. These core indicators could be used as a simplified and transparent decision-support-tool for decision-makers of major events and should provide a first overview of the sustainability performance of mega-event facilities (see fig. 3).

Figure 3: *Indicators for sustainable mega-event buildings* [2]

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Guidelines for Plus-Energy Mega-Event Buildings (Active+ Standard)

The aspect “energy” is animportant topic of the sustainability performance of mega-event buildings. Although arenas, like stadia or sports halls, have a huge energy consumption during the (sport) events, as well as during the “normal” operation phase (e.g. training, vacancy, etc.), concepts and guidelines for energy efficiency of mega-event buildings haven’t been considered so far. Also models for the infrastructural interaction with the neighboring buildings in terms of energy processes are still missing. As a result, many mega-event buildings, like stadia still have to deal with their huge energy consumption.

However, the the building type “mega-event venue” has strong potential and possibilities in terms of being an energy supplier and storage facility. Due to the large roof and facade surfaces and the massive constructions, mega-event buildings offer enormous potential for the use of renewable energy. With this energy both the arena, as well as the neighborhood could be supplied with energy. Similary the arenas could obtain energy from the surrounding neighbourhoods. However, the energy processes of a mega-event arena and their infrastructural connection with the neighborhood are very complex and until now poorly explored and analyzed. Therefore a reseach project was started in 2014 to develop guidelines for CO_2-neutral and plus-energy stadia. The project will analyse different scenarios for possible synergies and planning approaches for plus-energy approaches while considering the environmental, economical and social aspects as well. The main goals will be to analyse 7

possibilities for the interaction of arenas with the neighbourhood, producing energy by renewable energy sources, interconnection with the power grid and possibilities to storage energy in an arena,etc.

Figure 4: *Active+ standard as basis for plus-energy mega-event-buildings* [8]

The research project will be buildt upon the concept of “Active+” houses (see fig.4 and www. activhausplus.org). This is a new model that was founded in November 2013 by a German Non-Governmental Organization “Active+” with support of the Federal Ministry of Transport, Building and Urban Development (BMVBS). The focus of the Active+ initiative is the development of sustainable standards for plus-energy buildings and districts for the construction and the real estate industry. The Active+ standard will create a common plus energy standard on a building and district level and will combine energy efficiency and renewable energy production close to consumers’ utilities , building comfort and efficiency throughout the entire life cycle of buildings and districts [7].

References

[1] Essig, N. (2010). *Nachhaltigkeit von Olympischen Sportbauten (Sustainability of Olympic Buildings)*". Stuttgart. IRB Press

[2] Essig, N., Hiebel, M., Schneider, S., Jäger, M. (2012). *Leitfaden zur Bewertung der Nachhaltigkeit von Bauten für Großveranstaltungen (Guidelines for the Assessment of the Sustainable Performance of Buildings of Mega-Events).* doi:http://www.ins.din.de/cmd?level=tpl-artikel&menuid=52986&cmsareaid=52986& cmsrubi

[3] Preuss, H. (2004). *The Economic of Staging the Olympics: A Comparison of the Games 1972-2008.* Cheltenham

[4] Essig, N. (2013). Guidelines and Indicator for Sustainable Mega-Event-Buildings. in Proceedings SB 13 Graz Regional Sustainable Buildings Conference. Graz

[5] Essig, N., Gantner, J., Magdolen, S. (2012). *London 2012 -ein Ansatz für nachhaltigere Spiele? (London 2012 –An Approach for more sustainable Games).* Munich. doi: http://www.detail.de/architektur/news/london-2012-ein-ansatz-fuer-nachhaltigere-spiele-019406.html

[6] Essig, N., Hiniesto Munoz de la Torre, D. (2011). *OPEN HOUSE –an European Approach to Assess the Sustainability of Buildings*", in Proceedings SB 11 Helsinki World Sustainable Buildings Conference, 18.-21. October 2011. 462-464. Helsinki

[7] www.activhausplus.org

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Learning from the past: Training for a sustainable future of the tourist sector in the Coastal Atacama Desert.

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Abstract: *The Atacama Desert in Northern Chile is one of the driest places on Earth. Where this desert meets the ocean, the cold waters of the Humboldt Current and the Pacific Anticyclone produce a climate of consistently cloudy mornings and high humidity, yet with almost non-existent rainfall and clear afternoons with harsh solar radiation. Since pre-Columbian times mankind has inhabited this thin stretch of land between the ocean and the desert. Today the regions beaches, flora and fauna, the phenomenon of the flowering desert, important paleontological remains and its more recent history, are beginning to generate an increase in tourism. At the same time the region is threatened by illegal occupation for holiday homes and the social and environmental impacts of the mining industry. This paper presents a study of the region's vernacular and indigenous architecture, local materials and existing infrastructure, looking at how the past can suggest a sustainable future.*

Key words, Vernacular Architecture, Tourism, Sustainable Architecture, training.

Introduction

Inhabited since pre-Columbian times the coast of Chile's Atacama Region, a thin shelf of land where one of the driest deserts on earth drops abruptly to meet the cold Pacific Ocean, offers opportunities for tourism that are only just beginning to be developed. With some of the most beautiful beaches in Chile, such as *Playa La Virgen*, important paleontological sites such as *Cerro Ballena*, the phenomenon of the flowering desert which occurs only in certain years following the scarce rainfall, national parks and the historic influences of the mining boom and European immigration of the late nineteenth century, the region has a broad appeal to both national and international tourists. Between 2006 and 2010 foreign tourism in the region increased by 61% whilst in the same period visits to the region's national parks increased by 53% (Sernatur 2011). With this increase in tourism it is important that the tourist infrastructure is sustainable, both to preserve resources and the environment, and to compete in an ever more demanding international market. The region is already threatened by the environmental impacts of the mining industry and the illegal occupation of large stretches of coastline for the building of holiday homes for the inhabitants of the mining cities in the desert's interior. The former has contaminated water courses and in the worst example produced the build-up of over 320 million tons of toxic copper mining residue in the mouth of the river Salado in front of the town of Chañaral, an environmental disaster labelled as one of the most contaminated places on the planet (Cortés Alfaro 2010). The latter has led to the formation of illegal settlements without sanitary provision, basic services, emergency access,

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or considered planning. It is therefore imperative that the tourism does not further place a burden on the region but is instead a positive force.

In 2012 the Bioclimatic Laboratory of the Universidad Central de Chile was invited to participate in the Chilean government funded project “Hub for the dissemination of tools for the competitive sustainability of the tourist sector of the coast of the Atacama Region” directed by the Institute of Tourist Heritage of the same university. The assignment was to research sustainable construction for the region and to develop a series of workshops to share this knowledge with the local entrepreneurs involved in the tourist sector, with the aim of promoting best practice for a sustainable tourist infrastructure. There follows the results of the research which formed the basis for the three workshops that were undertaken in the region.

Climate and its impact on local construction

The climate of the region is produced by the meeting of the desert with the cold waters of the Humboldt Current and the Pacific Anticyclone. The climate is classified as BWn, “arid desert climate with abundant cloud cover” by the Köppen climate classification (Rioseco et al.). The characteristics of this climate are described by the Chilean standard NCh1079 of.2008 *Architecture and Construction- Climatic Dwellings for Chile and Recommendations for Architectural Design* (Russo et al. 2008) as “Desert zone with predominant maritime climate; little diurnal thermal oscillation; cloud cover and humidity which disperse at midday; strong solar radiation in the afternoons; zero precipitation in the north and scarce in the south; predominate winds from South and South West, with some interference from coastal breezes; atmosphere and ground saline; vegetation non-existent or scarce.” The standard goes on to describe the winters as temperate in the north of the climatic zone and cold in the south, and summers as hot with an average daily summer temperature of 20,4°C. The standard recommends that residential constructions should have a maximum thermal conductivity of 2.0W/m^{2}K for walls, 0.8W/m^{2}K for roofs, 3.0W/m^{2}K for raised ventilated floors and 5.8W/m^{2}K for windows. Considering average daily winter temperatures of 13.6°C the authors believe that these values should be lower, at least for the walls, and recommend a maximum U value of 0.9 W/m^{2}K. Other recommendations of the standard are; a minimum roof pitch of 10% for rough surfaces and 5% for smooth surfaces; solar protection to west-facing fenestration; protection to construction materials from the high humidity and saline content of the air; and the use of controlled ventilation in order to avoid excessive heat loss in winter.

In addition to the recommendations of the standard, the authors identified the following requirements for sustainable architecture in the region; solar protection to windows and external spaces to avoid overheating and provide shade, however when thermal mass is present solar radiation should be allowed to enter during winter months; protection from the wind especially during the cool mornings; the avoidance of deep plan forms to maximise natural daylighting; the use of thermal solar collectors for hot water and photovoltaic panels for electricity; and the careful management of water use, one of the regions scarcest resources, implementing the recycling of grey-water where possible. These recommendations formed the

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basis of the three workshops organised in the region, together with the following study of local architecture and materials.

Local, vernacular and indigenous architecture of the region

The indigenous people of the region now known as *Changos*, according to the local museum of Caldera, inhabited shelters composed of semi-conical structures of branches covered with grasses and seal skins, with a low base of dry stone walls. Similar structures can still be encountered today along the coast, used by the descendants of these people as either temporary or permanent shelters (figs 1 & 2). The low stone walls provide shelter from the coastal breezes and may offer some thermal inertia to provide comfort during the cooler nights and mornings.

Figure 1. Fishermen's shelter, Piedras Bayas.

Figure 2. Fishermen's shelter near Carrizal Bajo.

In the second half of the nineteenth century European immigrants arrived in the region drawn by the mining opportunities and the construction of Chile´s first railway linking the mining town of Copiapó to the port of Caldera. With them they brought an architecture of timber framed, timber clad houses, many prefabricated in North America. As a local adaption, the walls of these timber houses were infilled with a *quincha* (wattle and daub) a traditional local building technique consisting of a background of branches or split bamboos covered with an earthen render reinforced with straw. A notable example of this type of architecture is the *Casa Tornini* in Caldera (fig. 3).

Figure 3: Casa Tornini, built circa 1860, Caldera .

Figure 4:Detail of quincha wall build-up.

This house was built around 1860 for the North American William Wheelwright, the owner of the company that built the aforementioned railway, before passing first to the British consul

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of the time and then in 1907 to the Italian Tornini family who now run the house as a museum. The structure of Oregon pine was shipped in pieces from the United States and constructed with *quincha* infill, in this case using Guayaquil Cane bamboo (*Guadua angustifolia*) which arrived in Chile as shipping ballast. The bamboo is covered with a course earthen render of mud and straw, and finished with a finer render of mud and ashes (fig.4). The house has a covered veranda to the North, a feature common to many buildings dating from this period, and a glazed gallery to the East, a feature unique to this house.

Local materials

The following local natural building materials were identified by the authors. They have a historical use in the region and are now being rediscovered and used in contemporary constructions. Practical hands-on exercises of working with these materials were included in the workshops.

Totora (*Scirpus californicus ssp. Tatora*)

This sedge, *Totora,* is a subspecies of the Californian Bulrush or Giant Bulrush (*Scirpus californicus).* It grows in abundance in the few river estuaries that exist in the region, such as the estuary of the River Copiapó (fig.5). The stems of the plant can grow up to 4 metres in height and have a hollow cellular structure (fig.6).

Figure 5: Totora beds in the River Copiapó estuary.

Figure 6: Cut totora stem showing cellular structure.

This cellular structure gives the stems a good insulating quality with a coefficient of thermal conductivity λ calculated by the University of Minnesota as being 0,069W/mK (Niaquispe-Romero et al. 2011). The reed is traditionally used for roofing, wall coverings and windbreaks. For roofing the stems are doubled around horizontal timber roof poles and stitched together below the pole to secure. In modern application, a sheet of bituminous roofing felt is sometimes sandwiched between the doubled-over stems to provide greater water-tightness. For wall applications and windbreaks the stems were traditionally laid side by side and sandwiched between vertical branches or bamboo canes. A contemporary development of this technique uses lines of stitching running perpendicular to the stems to create mats that can then be applied to timber uprights. Given its coefficient of thermal conductivity the recommended U-value of 0.8W/m^{2}K for roofs (Russo et al. 2008) could be achieved with a thickness of 75mm and for walls 0.9W/m^{2}K with 65mm.

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Brea (tessaria absinthioides)

This shrub known locally as *Brea*, grows in only a few specific locations within the region, these being principally around the village of Totoral (fig. 7) and in some parts of the upper Copiapo river valley. The shrub has straight stems with a diameter of approximately 5mm which grows to a height of 1.5m. The stems are harvested in bundles (fig. 8) and used both as the infill background for *quincha* (wattle and daub) and as freestanding windbreaks.

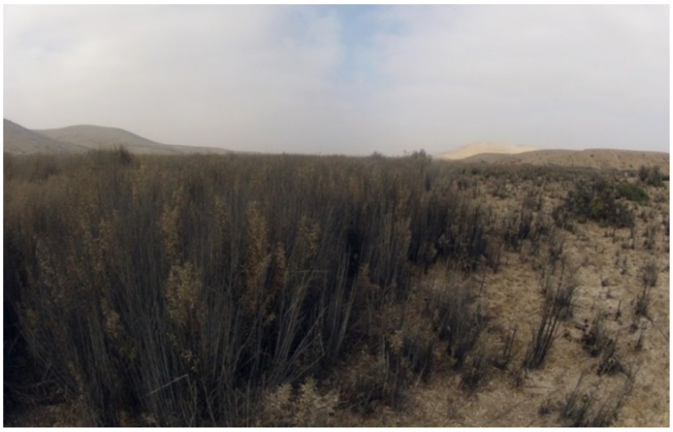

Figure 7: Brea growing near the village of Totoral.

Figure 8: Bunches of harvested brea

Stone

The stone used for construction in the region both historically and today is principally collected on the beaches as opposed to being quarried. Although traditionally used as dry stone walling, stone must now be used in conjunction with concrete and a rigid frame to provide resistance to seismic forces.

Examples of local contemporary sustainable architecture

There follows a selection of pioneering projects that draw on the traditional architecture and construction techniques, whilst at the same time incorporating other active systems with the aim of providing a sustainable tourist infrastructure. These examples were included in the presentations made to local entrepreneurs to demonstrate what is possible in the local context.

Hostal Boutique Ckamur, Caldera

This hostel aims to revive the pre-Hispanic past of the port of Caldera and the surrounding region, building with traditional materials and incorporating designs found on archaeological remains. The building (fig. 9) has a timber frame infilled with *quincha* using *brea* and earthen render. The roof is thatched with *totora* and grey-water is recycled (fig.10) to irrigate the plants on the north facing terrace and surrounding garden. Measurements of dry-bulb temperature showed an average indoor air temperature of around 16°C in winter with no heating. Measurements of globe temperature showed this to be consistently lower than the dry-bulb temperature suggesting that the thermal mass of the *quincha* can have a negative impact if direct solar radiation is not allowed to enter during winter months. This also indicates that a higher thermal mass construction technique such as adobe would not be suitable in this climate.

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Figure 9: Hostal Boutique Ckamur, Caldera .

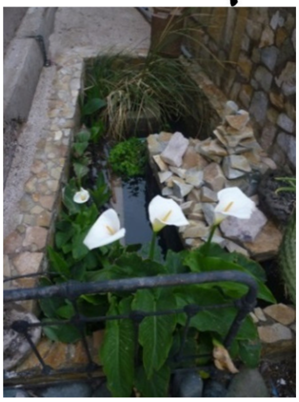

Figure 10: Grey-water recycling Ckamur, Caldera .

Base camp, Piedras Bayas

This project provides sleeping accommodation in 3 geodesic domes, however it is the communal kitchen/dining area and associated bathroom and offices (fig. 11) that are perhaps more interesting. These use a contemporary application of the local material *brea*. The *brea* is left exposed, confined in timber frames, with a layer of glazing or plywood on the inner face of the panel to improve air-tightness. Clear windows, free of *brea*, provide carefully selected views (fig. 12). The same system is used to provide external windbreaks but without the secondary layer of glazing or plywood. Electricity is provided by photovoltaic panels, however hot water is provided by gas boilers. The entrance to the site is delimited by low dry stone walls reminiscent of the bases of *Chango* dwellings.

Figure 11: Bathroom and offices, Base Camp, piedras Bayas. Figure 12: View out showing brea cladding

Lodge Pan de Azúcar, Pan de Azúcar National Park

This complex of cabins and camping is located within the National Park of Pan de Azúcar (Sugar loaf), so named because of the shape of the offshore island that dominates the park. The construction technique is the same as that used at Hostal Ckamur with walls of *quincha* earthen rendered *brea* and *totora* roofs. Hot water is provided by evacuated tube thermal solar collectors, the only example of thermal solar panels encountered by the authors in the region. Previously electricity was generated by a wind turbine and photovoltaic panels, however this installation was destroyed by storms and electricity is now provided by a diesel generator as the complex is not connected to the national grid. Bottled gas is used for cooking and for powering the refrigerators in the cabins.

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Training Workshops

Using the results of this research a "caravan" of workshops was organised. These took place in three geographic locations, one in the north of the region, one in the middle and the other in the south. This was intended to reduce the travel distances of the participants and reinforce the importance of local rather than centralized initiatives. Those who took part were local entrepreneurs and those involved in the tourist industry. These workshops included interactive presentations and hands-on experience of using the natural building materials identified.

Conclusions

The researched showed that there exists low carbon, natural building materials in the region that have been historically used in the vernacular and indigenous architecture and which are now being rediscovered by local ecologically minded entrepreneurs. Whilst the availability of these materials is not equally spread across the region, thereby requiring some transportation, they are more local than other conventional building materials that must be transported from the south of Chile over 1000 km away.

Although the climate is an arid desert climate the authors believe that thermal insulation is necessary to improve thermal comfort in the cool winter months and cloudy mornings. Other than the insulating properties of the roofing material *totora*, thermal insulation was not encountered in either the traditional or contemporary architecture. It would be interesting to think how insulation could be combined with the construction technique *quincha* in order to provide ecological walls with limited thermal mass and good insulating properties.

It is hoped that the workshops that resulted from this research have highlighted to the local tourist industry the potential of the local materials, seen in the vernacular and indigenous architecture, to provide a sustainable future for the regions tourism, learning from the past.

References

Cortés Alfaro, M.F., (2010) *El Muerte Gris de Chañaral,* Heinrich Böll Stiftung Cono Sur, Chañaral, Chile.

Ninaquispe-Romero, L., Weeks, S. y Huelman, P. Totora: A Sustainable Insulation Material for the Andean Parts of Peru. *In Pasive and Low Energy Architecture PLEA 2012*, Lima, Peru, Nov. 2012.

Rioseco, Reinaldo y Tesser, Claudio : *Cartografía Interactiva de los climas de Chile* [online]. Instituto de Geografía. Pontificia Universidad Católica de Chile. Available: www.uc.cl/sw_educ/geografia/cartografiainteractiva [22/05/2014]

Russo, H., Rodríguez, G., Behm, H., Pavez, H., MacDonald, J. and Testa, M., (2008) *Architecture and Construction- Climatic Dwellings for Chile and Recommendations for Architectural Design, Chilean Standard NCh 1079 of 77 (2008)*, Instituto Nacional de Normalización, Chile

Sernatur (Servicio Nacional de Turismo de Chile) (2011) *Plan para el Desarrollo Turístico de la Región de Atacama,* Gobierno de Chile, Santiago de Chile