WORLD SUSTAINABLE BUILDING 2014 BARCELONA CONFERENCE

Sustainable Building: RESULTS

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CONFERENCE PROCEEDINGS

VOLUME 4

This is the fourth 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 morning of day 3 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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CIB: Conseil International de Batîment
FIDIC: International Federation of Consulting Engineers
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DAY 3

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Session 117:

What are the keys to produce and maintain housing with less impact?

Chairperson:

Gomes, Vanesa

Associate Professor. University of Campinas, Brazil

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An ongoing evaluation of single-family passive housing in Norway

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Abstract: *This paper presents an ongoing evaluation of single-family passive housing in Norway. Results from measured and calculated energy end use and interviews on perceived comfort and general satisfaction with inhabitants in 3 housing areas are presented. We also present results from measured indoor environmental parameters such as indoor air temperature and relative humidity from 2 of the projects. The qualitative interviews with the residents showed a high level of general satisfaction in all projects. In one of the project some users experienced indoor temperature during winter as cold. During the heating season we measured an average indoor temperature of 20.1 to 24.6 ^{0}C in the two projects. Summer temperature was experienced as comfortable. The level of relative humidity was satisfactory during the heating season with an average of 35-40%, but was on some occasions as low as 11%. This confirms residents` experiences with dry air during winter. The energy use was higher than the calculated especially in one project. High indoor air temperature correlated with high energy use. Data used in the energy calculations anticipated an average indoor temperature of 20.3 ^{0}C. Findings from measurements of indoor temperature and statements from residents indicate that the general level of comfort and expectations towards indoor temperature among many inhabitants are high, e.g. wearing a T-shirt indoors all year round in Norway seems to have become common. If actual comfort temperature is higher than anticipated in simulation programs, energy calculations and actual energy use/measurements will be difficult to meet.*

Key words: Passive houses, user satisfaction, energy end use, indoor environment

Introduction

This paper presents preliminary results from the ongoing Norwegian research project "EBLE" (2012-2016). The project`s aim is to increase knowledge about passive housing through an evaluation of pilot projects. The background for the study is that there are few systematic studies of how passive housing works in Norway and Norwegian climate. Studies of passive houses in Sweden, Germany and Austria show that although many projects on average are close to calculated energy use, there are large individual differences in energy use on residential / apartment level (Schnieders 2003, Janson 2010, Dokka et al. 2011, Bagge et al. 2012). In Norway, there has been specific interest in the question if passive housing does have a positive or negative impact on indoor climate parameters and resident`s perceived comfort.

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Cases and method

The housing area we report from in this paper is located in the south-west part of Norway, close to the city of Stavanger. The area contains in total 18 single-family passive houses of three different building types, constructed by three different building companies according to Norwegian Standard NS 3700.



Figure 1: location in Norway (gulesider.no). Figure 2-4 the three different building types. 1: Fjogstadhus project, 2: Block Watne project; 3: Jadarhus project (pictures: SINTEF).

Project	***Studied***	***Heating system***	***Ventilation***	***Main construction***
Fjogstadhus, 9 houses 161 – 238 sqm	*measurements in 9 houses, 5 interviews*	*Air-water heatpump, hydronic floor heating bath, one radiator/storey*	*Balanced ventilation/heat recovery*	*On-site construction, timber frame*
Block Watne, 5 houses 158 sqm	*measurements in 2 houses, 1 interview (2nd planned)*	*Electric floor heating bathroom and corridor, wood stove*	*Balanced ventilation/heat recovery*	*On-site construction, Timber frame with Iso3 pillars (insulated wood pillars)*
Jadarhus, 4 houses 249 sqm	*measurements in 3 houses, 3 interviews*	*Air-water heatpump or geotherm. heatpump, hydronic floor heating*	*Balanced ventilation/heat recovery*	*On-site construction, Timber frame with Iso3 pillars (insulated wood pillars)*

Tabel 1: Facts on projects.

The methodological approach chosen is case study (Yin, 2013). Researchers from different fields are involved and the study is based on qualitative and quantitative data. We have measured and calculated energy end use, measured indoor environmental parameters such as indoor air temperature and relative humidity in 15 of the 18 houses. Not all measurements are completed yet, so indoor environmental parameters are only reported on for two of the projects (11 houses). We have conducted qualitative interviews with 9 of the inhabitants on perceived comfort and general satisfaction after the first year of residency.

Findings

Indoor air temperature and resident`s perception

Most Fjogstadhus residents thought that indoor temperature was comfortable, both in winter and summer. However, some residents found that indoor temperature sometimes was too cold during the first winter.

The resident interviewed in the Block Watne house perceived indoor temperature as comfortable. He chose to have a low indoor temperature also during winter, according to his own perception between 18-20°C. He has switched off the heat recovery of the ventilation and during spring and summer he also switches of the electric floor heating. He uses the wood stove in the afternoon during winter.

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Level of satisfaction with indoor temperature was also high in the Jadarhus project. All residents said that comfort experience has increased significantly compared to their old houses and that they can have constant temperature in most of the rooms. One couple said that they wear T-shirts all year round. Only one of the three households in Jadarhus mentioned that the 3rd floor which they only can heat with ventilation heat recovery is sometimes cold. The other floors have hydronic floor heating.

The measured average indoor temperature in the livingroom/kitchen in Fjogstadhus (blue bars) and Block Watne houses (red bars) is shown below. The green bars show the average temperature in two of the Fjogstadhus houses measured by Tinytag sensors placed below the dining table in the living room. They were installed as a control for the results of the other sensors which were placed in the kitchen/living room ventilation extract air duct close to the roof. Comparing results from the different sensors the measurements in the two houses indicate that the sensors in the extract air duct shows a temperature approximately 1 °C over the room temperature.

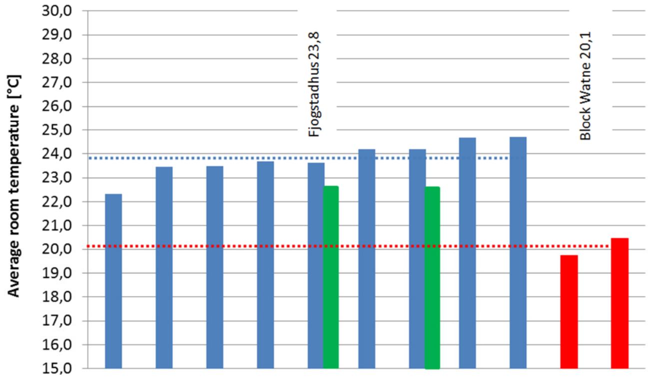

Figure 5. Average room temperature in the livingroom/kitchen of 9 houses constructed by Fjogstadhus and 2 houses constructed by Block Watne. The measuring period was an eight month period from 01.09.2013 to 01.05.2014.

Measurements showed a relatively high indoor temperature in Fjogstadhus houses both in winter and in summer with an average temperature of 23.8°C (Tinytag control sensors: about 22.5°C). BW houses show a much lower average temperature of 20.1°C. Experience of cold indoor temperature reported by some residents in Fjogstadhus houses is difficult to explain by the measurements. Indoor temperatures in the Fjogstadhus houses during a period with low outdoor temperature from 16.01.2014- 26.01.2014 also stayed on a high level, between 20-26 °C. Temperatures in BW houses are lower.

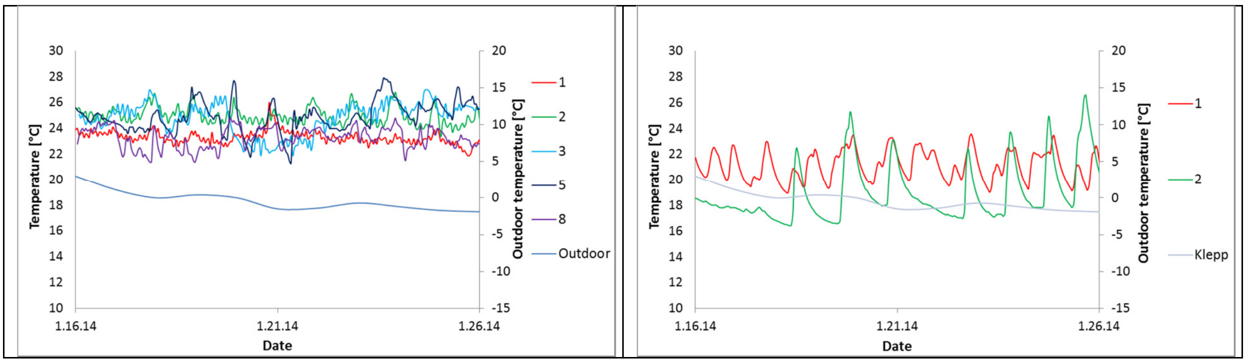

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Figure 6: Indoor temperatures in the Fjogstadhus and Block Watne projects during a period with low outdoor temperature. House 4 in Fjogstadhus was unoccupied and is not taken into consideration. (Interviews were conducted in house 9,8,7,5,1 in Fjogstadhus and in house 2 Block Watne.)

Some Fjogstadhus houses show high temperature variation over the day. Also the Block Watne house number 2 shows varying temperatures, with low temperature during the night and daytime (down to 17°C) and higher temperature in the evenings (up to 25 °C). The measurement at BW illustrates the great effect of the wood stove which the resident uses in the evenings during winter. The measurements also confirmed the residents` statement that he keeps the temperature low most of the day and night. Block Watne house 1 shows a higher average temperature with typical two temperature peaks during the day, one in the morning, and one in the evening.

Two of the Fjogstadhus residents who intially were discontent with winter temperature informed us later that they have exchanged parts of the heating system and they were more content afterwards. One of these households had also installed an additional heating source, which is still used. In this household we measured the highest average temperature (and also the highest energy use).

Overheating during summer was of lesser concern in all projects. Residents said that it is enough to air out when it sometimes gets too hot. Two of the couples in Jadarhus houses pointed out that they were surprised that the houses kept a comfortable indoor temperature also during summer. An exception is one Fjogstadhus household that complained about too warm indoor temperatures in summer. In this Fjogstadhus house we measured the greatest number of hours above 26°C during summer (801 of 8148 measured hours, lowest number: 115). None of the residents in all three projects had installed exterior shading, which could have contributed to better temperature control during the summer.

Relative humidity measured and resident`s perception of air quality

All interviewed residents in the three projects were generally satisfied with the fresh air supply and the perceived air quality, particularly during summer. Some experienced air quality as too dry in winter.

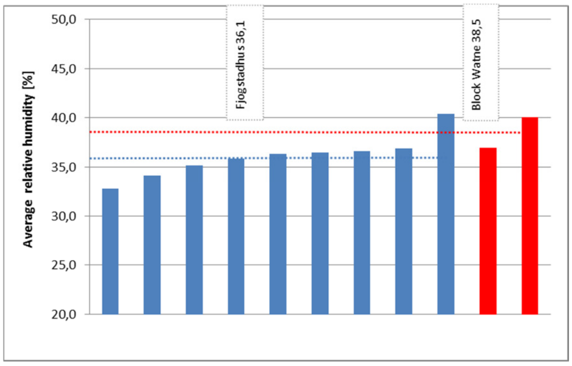

Figure 7: Average relative humidity in the livingroom/kitchen of Fjogstadhus and Block Watne houses.

The fresh air supply through the ventilation system was perceived as very good in all projects, and most residents reported consequently less need for window ventilation than in their

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previous homes, also in the bedroom. One Fjogstadhus household was an exception and stuck to old habits. They had the bedroom window open all night and day all year round. The main reason for this behaviour was the notion of feeling cooped up when the window is closed and the wish for low temperatures in the bedroom (as cold as possible).

Two Jadarhus households set down the level of air supply from 2 to 1 during the night due to noise. All Jadarhus household complained about the noise level of the ventilation vents, especially in the main bedroom. Noise from ventilation was the main issue of complaint in the interview with Jadarhus residents. Residents in the other two projects were less bothered by ventilation noise. Some mentioned that there is some noise when ventilation is on the maximum level.

Energy use

Total energy use has been measured in 15 dwellings. Nine of the houses have been monitored for 2 years. Sub-metering is still ongoing in 5 of the dwellings, but inital installation problems caused that data are not yet available. The outdoor temperature in the first and the second year of measuring was significantly different: -1.0 °C under the normal temperature during the first year and +3.0 °C over the normal temperature during the second year. During the second year, the delivered energy use in Fjogstadhus houses was reduced with 6 - 24 % in 6 of the dwellings, but also increased in 3 of them. The mild winter during year two can explain reduction up to 8%. Despite the reduction, still only two of Fjogstadhus houses use less energy than calculated. In the Block Watne houses the energy used in the mild winter was less than the energy calculation and also in Jadarhus two of the houses were under the calculated values (one of these was temporarily not occupied).

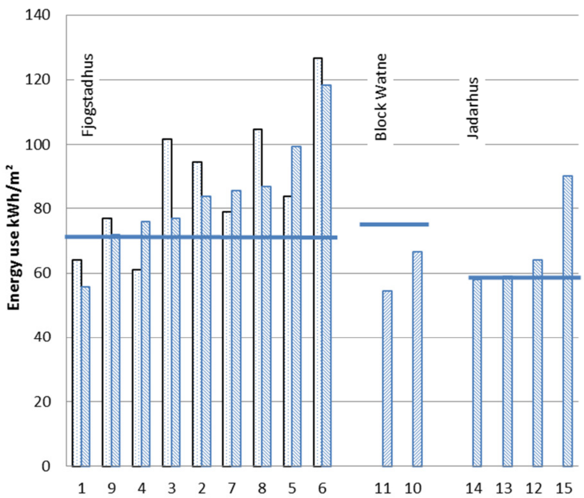

Figure 8. Energy use in year 1(dots) and year 2 (diagonal) for 15 houses. Horizontal bar: Energy calculation with locale climate.

The indoor temperature can affect the energy use in the dwelling significantly, standardized values of 21 °C during the day and 19 °C during the night are used in the energy calculation. An increase of the indoor temperture from average 20.3 °C to 23 °C, as measured in Fjogstadhus houses, increases the delivered energy with 4.5-6 kWh/m² depending on the size of the house. The Block Watne houses have a different heating system and both houses measured a relatively low indoor temperature. Unusual for passive houses, they have a wood stove, whose use is reflected in low delivered energy. In the Jadarhus project one house stands out with a high delivered energy when compared to the other houses and compared to calculations. Most of the households interviewed did not focus much on saving energy. Living in a passive house and thus saving energy was a bonus to the interviewees. Some households were interested in their electricity bill and some were surprised by how much energy they actually used, despite living in a passive house. Some were not sure why they use as much energy as they did. These issues will be further investigated.

Conclusions

Differences and similarities between the projects

General satisfaction was high among residents (with one exception at Fjogstadhus). Most residents pointed out that comfort experience had increased significantly compared to their old houses. Air supply through balanced ventilation was perceived satisfactory in all projects. Air quality was sometimes experienced as too dry during winter. Noise from ventilation system was reported as negative from Jadarhus residents.

We also found differences in the satisfaction with and expectations towards indoor temperature during winter. Heating systems differ from project to project and in several cases discontent was linked to effect of heating system or temporary errors with the system. Block Watne houses had the most basic heating solution of all the three projects, with electric floor heating in the corridors and the bathroom, pluss wood stove. The resident interviewed was however satisfied. The type of heating system is reflected in high variation in indoor temperatures, as well as it is probably also a reason for low energy use. However, without the results from sub-metering, we cannot conclude on this for sure.

Most residents seemed also to cope better with adjusting to warm indoor summer temperatures than to colder temperatures. Opening windows, using indoor shading, or taking on/off clothing were perceived as sufficient to regain personal comfort.

Findings from measurements of indoor temperature and statements from residents also indicate that expectations towards indoor temperature are high among many residents. Some residents named that wearing T-shirts all year round is a comfort indicator to them. Most residents estimated that they had 22-23^{0}C as normal temperature indoors instead of 20.3^{0}C which is used as average comfort temperature in common simulation programs. Measurements often showed even higher values than residents` estimations. Highly insulated and air tight houses such as passive houses can retain a high temperature in all rooms. When high expectations towards thermal comfort have become common for many residents (with some exception as the interviews showed), this may be one reason for why an indoor air temperature of 20-21^{0}C can be experienced as cold, as illustrated by the statements of Fjogstadhus residents. If actual comfort temperature in most houses is higher than anticipated in simulation programs, energy calculations and actual energy use/measurements will be difficult to meet. Calculations conducted in the Fjogstadhus projects showed that an increased indoor temperature from 20 to 23^{0}C increases energy demand with up to 9 % (SINTEF, 2014). Both energy and temperature measurements in the two BW cases are closer to calculations. One reason for this may be differences in heating systems. However, also residents´ practices and comfort level are of importance. As long as we do not have information from sub-metering we can also not differentiate between energy use for heating, warm water and other appliances. This information will moderate the picture and give more detailed information and conclusions.

Topics for further research

In Norway, also passive houses are built with a heating system (Norwegian Standard 3700). Heating systems chosen differ from project to project. There is little evaluation and documentation on which heating system works well for the residents and there is a lack of guidance for the building companies on what type of heating system to choose.

The study confirms also a commonly acknowledged gap on how difficult it is to match calculated energy use and actual (and varying) energy use in households. It should be further evaluated whether input data in energy calculations could be adjusted, e.g. the values used for normal comfort temperature, in order to get more realistic results.

Acknowledgment

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Evaluation of the Ecological Footprint of residential buildings in terms of its construction typology

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Abstract: *The model that assesses the ecological footprint (EF) in buildings, which is based on the EF methodology, the building project and the Andalusia Construction Cost Database is validated. For analysis and model validation, 100 residential project´s database, from one to ten floors, are evaluated. The model is improved by calculating the EF of the construction chapters defined in the classification of the Andalusia Construction Cost Database; the work is broken down into the resources used (materials, machinery and manpower).*

Keywords: ecological footprint, resources, buildings, construction break down system.

1.-Introduction

The present model to assess the ecological footprint in buildings is based on the EF methodology defined by Solis et al. [1], the building project and the Andalusia Construction Cost Database (ACCD) [2]. For the analysis and model validation a database of 100 residential projects, from one to ten floors, are evaluated [3]. Finally, the best building systems are identified from the point of view of the impact they have on the planet according to the EF indicator [4].

2.- Methodology

The present methodology divides the work into four phases: data collection, the EF methodology application, a comparison of the EF values per different constructive solutions and construction chapter. The construction chapter refers to the project subdivisions included in the ACCD systematic classification.

2.1.- Data Collection: In this section the following tasks are carried out: real project selection, ranking them by the number of floors above and below ground, type of foundation and roof, and other structural characteristics.

The EF calculation is divided into the project chapters: foundations, structure, facade, carpentry and roof; the present analysis focus on the foundation in order to explain the methodology. According to statistical data collection and information analysis [5], most buildings constructed in Spain are residential buildings of 4-6 floors above ground. Therefore, the 4 floors above ground typology have been chosen, with a 22 sample size. The last are divided in with or without underground floor. And finally, those are classified according to the foundation type: reinforced concrete slab, isolated footings and piles. The roofs are flat or

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pitched. The buildings ground floor is for commercial purposes and it is delivered without finishes or installations.

2.2.- Apply the EF methodology: Once the projects are classified the EF model is applied [1] using the project budget and the ACCD [2]. The following steps are followed:

- Separate the project data: budget data, quantities (Qi) and general data.
- Determine the resources quantities required by each project per ACCD.
- Generate the resources quantification database (RQDB) [3], which is based on the ACCD, and calculate the specific project quantities to be analyzed.
- Calculate the EF using the model [1]. Also the partial ecological footprints are calculated: energy, crops, sea, pastures, forests and area consumed, those are added giving up the total EF for each project (Figure 1).

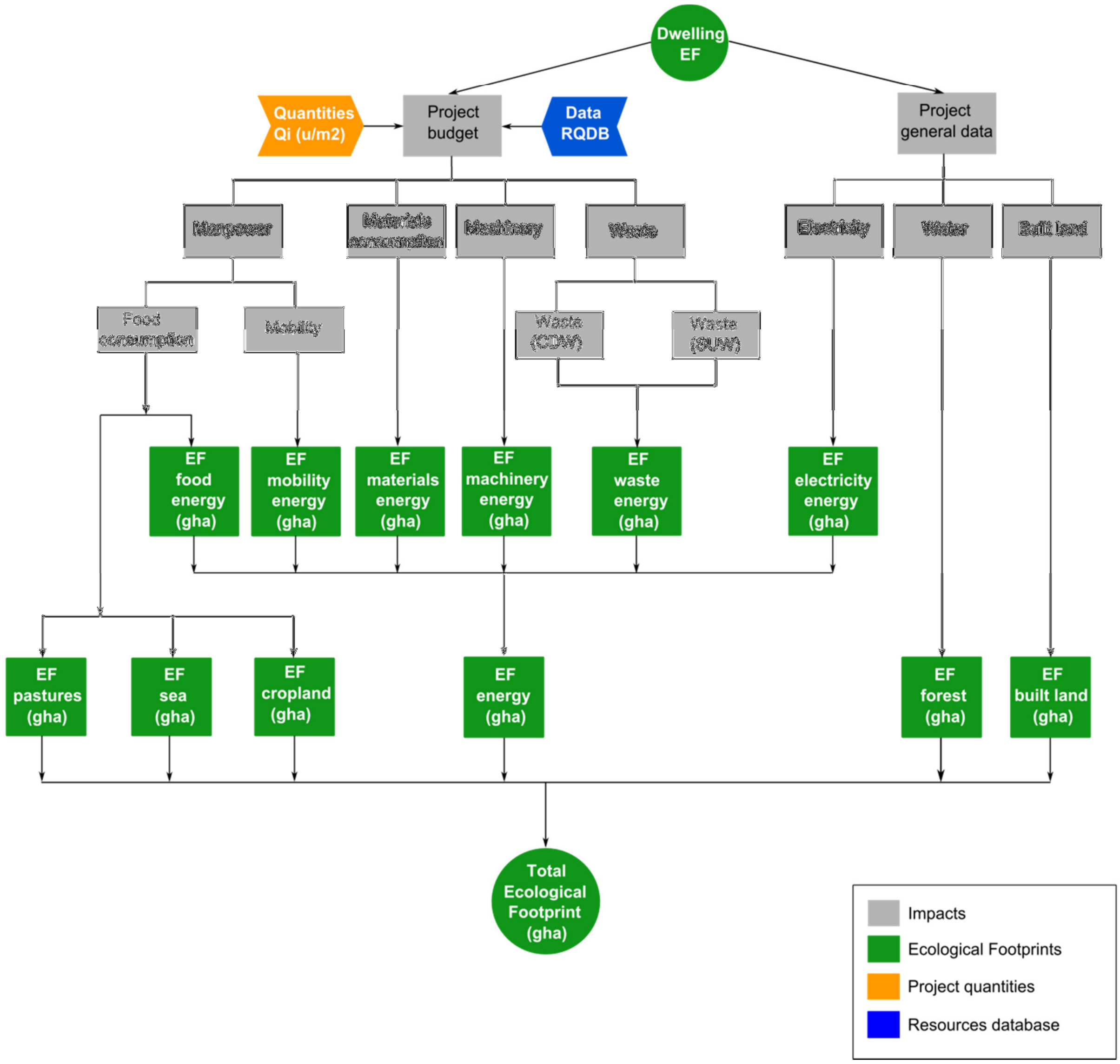

Figure 1: Methodology flowchart [3]

For analysis, the project is divided into two main parts: project quantities and budget, and general project characteristics.

- The project quantities and budget define the resources: material, machinery and manpower employed during the building construction.
- The general data does not depends on the budget quantities but on the built area, energy and water consumption in the construction site, and the work execution period.

The data obtained from the resources quantities (Qi) [3] of each project are structured according to the systematic classification of the ACCD, and are expressed in units per square metre constructed (u/m2). The ACCD [2] defines the resources quantities used in each of the units which are part of the project, when combining this data with the project quantities (Qi) we obtain a new database called resource quantification database (RQDB) [3]. The RQDB data is used in order to apply the EF methodology [1], which represents the total resources: manpower (hours), materials (appropriate units) and machinery (hours). The general project data, as defined previously, is the electric and water consumption during the building construction, the built area and the execution period. The EF calculation model is represented in Figure 1 [3], and determines the total EF, which depends on different partial EF: energy, pasture, sea, crops, forests and built land. These come from the impacts generated by the resources and energy consumption, waste generation and CO2 emissions. During the construction the following impacts are defined: electricity and water consumption in the construction site, manpower food consumption and mobility, construction materials, construction and demolition waste (CDW), municipal solid waste (MSW) and, finally, the built land. Specific calculations for each of the footprints and the total building EF are developed by Solis et al. [1].

Therefore, the quantities data and general information about each project, ancillary data for the calculation of partial EF and the development of complementary hypotheses determine the partial footprints and thereafter the total EF of each of the projects is analyzed.

The analysis is performed to the 12 projects selected, which are 4 floors above ground and one floor underground, and classified according to their foundations.

2.3.- Compare the values of EF obtained: a comparison is done with the EF obtained for the different residential buildings analyzed in terms of various construction systems.

2.4.- Calculation of EF sections divided according to the project: in order to perform the analysis of the buildings construction according to its structural characteristics and systems:

- Each chapter in the ACCD systematic classification is identified and represents a construction work stage.
- Each chapter EF is determined.
- A comparison between each chapter impact and its percentage with respect to the overall building footprint is calculated.

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Once these data are obtained, the EF of each building systems can be controlled during the project design, then taking into account sustainability aspects of the building to be constructed with respect to other possible designs.

3.- Results

The results are classified depending on whether or not the buildings have an underground floor, and in each of these groups a comparative foundation systems is used. The numerical coding of the 12 projects comes from the 100 projects originally studied [3]. Furthermore, the results show only the EF that comes from the project quantities and budget. In previous studies, the other impacts, which come from the general project data, represent about 26% of the total EF.

Partial EF (gha/m2)	Type of foundation											
	Reinforced slab				Isolated footings				Piles			
	89	93	97	101	26	41	44	49	72	73	74	75
Energy	851,87	777,73	841,73	767,17	807,97	733,47	797,40	723,74	771,67	845,66	835,93	762,28
Forest	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38
Pastures	153,00	135,13	148,44	130,66	150,50	132,63	145,94	128,07	139,79	157,62	153,26	135,23
Sea	104,16	91,99	101,06	88,95	102,46	90,29	99,35	87,19	95,17	107,30	104,34	92,06
Cropland	55,41	48,93	53,75	47,32	54,50	48,03	52,85	46,38	50,62	57,08	55,50	48,97
Built land	0,35	0,35	0,35	0,35	0,35	0,35	0,35	0,35	0,35	0,35	0,35	0,35
Total EF (gha)	**1165,17**	**1054,52**	**1145,71**	**1034,83**	**1116,15**	**1005,15**	**1096,27**	**986,10**	**1057,98**	**1168,39**	**1149,77**	**1039,28**
Total EF (gha/m2)	**0,210**	**0,190**	**0,206**	**0,186**	**0,201**	**0,181**	**0,198**	**0,178**	**0,191**	**0,211**	**0,207**	**0,187**

Table 1. Partial and total EF of residential projects, 4 floors above ground and one underground, the projects are classified according to the foundations types

The projects that have four floors above ground and one underground have higher EF when the foundation has piles (c73) or concrete slab (c89); isolated footings (c41 and c49) have smaller footprint. However, the total EF does not strongly depends on the foundation, other project aspects may have greater or lesser impact.

The project that has the largest total footprint is also c73 with piles foundation, the ground floor has dwellings, and its roof is flat. Differences with other projects in the same group are: c74 and c75 which are pitched roof, and c75 and c72 which have the ground floor for commercial purposes instead of dwellings.

The following project with high impact is c89 whose foundation is a concrete reinforced slab. The ground floor is occupied by dwellings and the roof is flat. The other projects c97 and c101 have pitched roof, and c93 and c101 have the ground floor for commercial purposes.

Finally, the two projects with the smallest footprint are c41 and c49, and the foundation is made of isolated footings. Both projects have the ground floor for commercial purposes, and different roof type: horizontal and pitched, respectively. The remaining two projects are c26 and c44 which differ from the previous ones because have dwellings on the ground floor, and the roof types are horizontal and pitched, respectively.

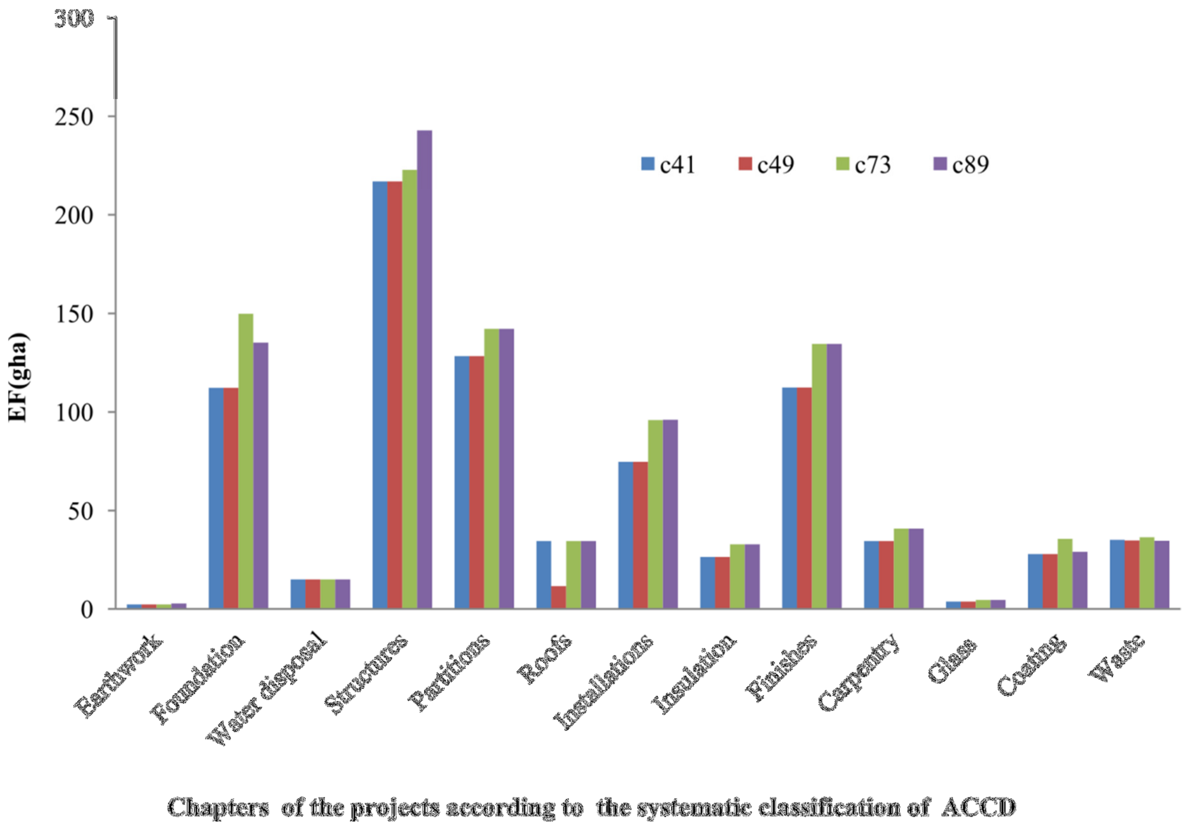

Figure 2. EF resources residential buildings 4 floors above ground and one basement floor with higher and lower EF classified by type of foundation

From the analysis of the residential buildings EF, the foundation is not a determinant characteristic by itself. A deeper analysis is needed in order to determine the most influential aspects in each chapter and focus on how to reduce its impact by means of different constructive solutions. In order to properly identify which project chapters produce a high impact in the EF, the resources are divided by ACCD chapters, and the projects are analyzed (Figure 2). The structure EF is the highest, followed by the foundation, finishes, partitions and installations impact.

In Figure 2, the buildings with piles foundation have a significant impact in the overall value of the EF, on the other hand, the ones with isolated footings, the foundation is the third important factor, and the building masonry has a higher impact.

In Figure 3, the EF of project c 49 is represented per project chapters. The structure EF is mostly due to the construction materials and its corresponding embodied energy, which has a higher value that the manpower or the machinery. In the other project chapters, materials also produce most of the footprint except for the finishes chapter, where a substantial increase in the footprint is produced by manpower, because the chapter is labor intensive. In the other

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chapters, the manpower also produces a significant impact but smaller than construction materials EF. The machinery EF is only presented in the excavations.

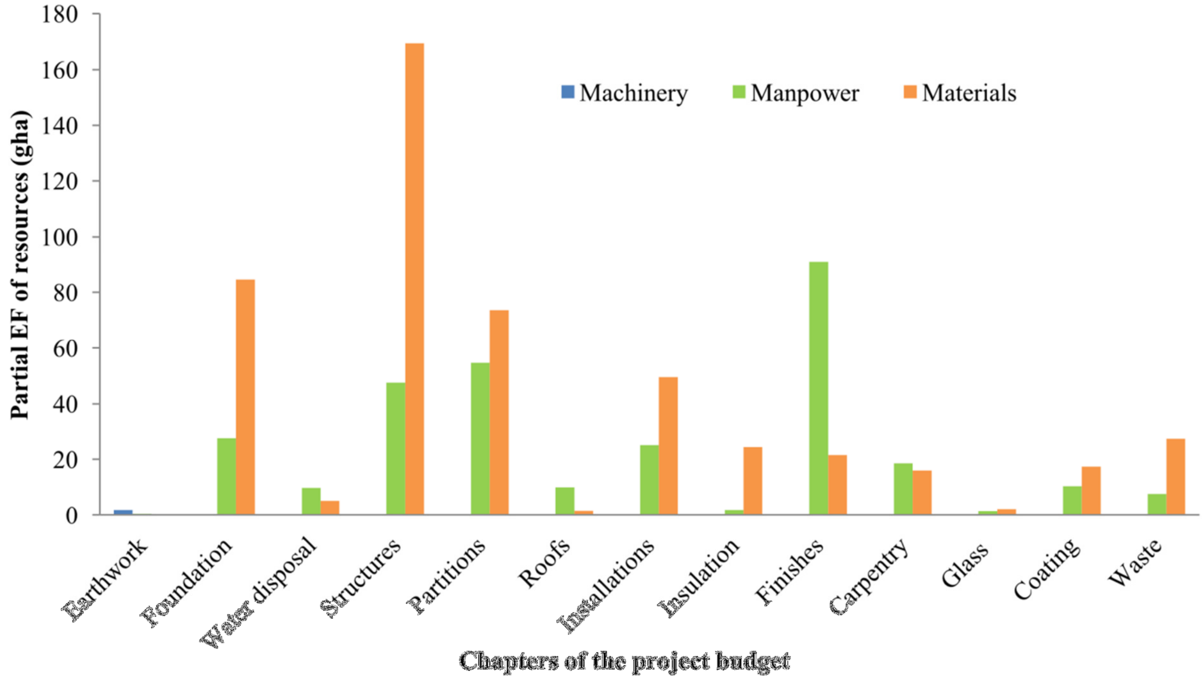

Figure 3. EF of the resources used in the construction of c49 project, residential building with 4 floors above ground and one basement floor and foundation with isolated footings.

4.- Conclusions

According to the results the EF indicator is sensitive to changes on the building type and construction system employed. The indicator assesses the impact caused by the construction of residential buildings and allows the optimization of resources during the design phase by means of different solutions assessment.

From all the building project chapters analyzed, the structure has the highest EF. In the particular case of the foundations, the projects made with isolated footings have the lowest EF of the three systems studied. The EF at this stage of the building can be reduced during the design by choosing a foundation with less impact.

The structure materials used are concrete and steel in the projects analyzed, both materials have a high embodied energy. In order to reduce its EF alternative constructive solutions such as timber frames or load-bearing walls can be used.

The remaining chapters with a high EF are partitions, foundation, finishes and installations, mainly due to the materials embodied energy and the manpower needed.

The materials and manpower are the resources that have the highest impact in the EF indicator. The EF can be improved by performing more extensive studies of these resources and control its corresponding impacts.

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5x4: A Case Study in Low Energy Infill Housing

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Abstract: *5x4 is a small infill housing project located in inner-suburban Melbourne, Australia. The main aim of the project is to create a low energy building that minimises the long-term environmental impacts of its occupants using passive and active eco-driven processes, materials and performance considerations. This paper describes the process of assessing and optimising the project's energy performance. This included a quantification of predicted operational energy demand as well as its embodied energy over a 100 year period.*

A range of potential construction materials were analysed and appropriate solutions selected. Embodied energy was calculated using a comprehensive hybrid approach, whilst IES-VE software was used to model the operational energy demands. Transport energy demands were significantly reduced compared to a project located in an outer-suburban development. The project also relies on existing infrastructure minimising the embodied energy demand associated with the construction of new infrastructure, typical of greenfield developments.

Keywords: low energy; infill housing; Australia; life cycle energy analysis

Introduction

The 5x4 project is a new infill housing development under construction in the city of Melbourne, Australia. The project uses a number of innovative systems, materials and construction techniques as well as an optimised building envelope, air tight construction and phase change materials to minimise life cycle energy demand as much as possible.

In order to determine whether design solutions will result in a reduction in energy demand, the energy performance of a building project must be assessed. To ensure a net reduction in life cycle energy demand is achieved the traditionally limited focus on improving building operational energy efficiency must be considered in the context of a building's life cycle energy demand, thus ensuring demands aren't inadvertently shifted from one life cycle stage to another. This is particularly crucial in operationally efficient buildings like 5x4 as the indirect, or embodied, energy requirement is proportionately more significant.

The aim of this study is to demonstrate the extent to which household energy demands can be reduced through appropriate siting, design and material selection. Comprehensive assessment techniques are used to quantify the life cycle energy demand of the 5x4 project which is then compared to the performance of an identical house located in an outer-suburban area.

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Background

The world's population is increasing at a rapid rate with most people now living in cities [1]. With this comes the need for new housing. In countries such as Australia, where land is in abundance, the response is often one of low-density urban sprawl. However, many cities are struggling to cope, finding it increasingly difficult to fund the infrastructure needed to support these new developments. They are also increasingly competing with prime agricultural land.

There is a growing understanding of the need to move away from low-density urban sprawl as a solution to the world's housing crisis [2,3]. This helps to retain land for agricultural and recreational purposes and aims to maximise the use of existing infrastructure (essential services, roads, schools, shops, hospitals etc.). A preferred housing model is one where new housing is built within established city and inner-suburban areas as well as surrounding outer-suburban activity centres [4]. This infill or higher density housing suits an increasing number of people (professionals, couples and small families), who prefer reduced commuting times to study and work, close proximity to community activities and low maintenance properties.

Another aspect that is becoming of increasing importance for future housing is the minimisation of its effect on the environment, especially in terms of the energy used during its production and operation. So important is this that the IPCC identify buildings as being a *critical* component of a low-carbon future [5].

The idea of Zero Energy Housing (ZEH) has been growing over the past decade. ZEH strives to reduce the need for non-renewable energy resources during the operation phase by, firstly, using a variety of approaches to minimise the energy required for heating, cooling, lighting and appliances, such as thermal insulation, thermal mass, appropriate orientation and planning and the use of efficient appliances, and secondly, meeting any remaining energy demands with the use of renewable energy systems (such as wind or solar power).

However, many existing examples of ZEH, such as the Australian Zero Emission House in Melbourne and the Beddington Zero Energy Development in London, do not attempt to offset the energy associated with material manufacture and the construction process, better known as a building's embodied energy. It is no longer acceptable to address only operational energy requirements, as was once commonly the case. It is now more widely understood that a life cycle perspective needs to be used as embodied energy demands across a building's life cycle can often be more significant than operational energy [6,7] and reductions in operational energy can sometimes shift the demand for energy to other stages in the building life cycle.

Description of the 5x4 project

The 5x4 project is currently in the construction phase. When complete, it will occupy a five metre by four metre site at the end of a narrow laneway within a built-up residential area less than three kilometres from the Melbourne CBD (Lat. 37°49´S, Long. 144°58´E), in the suburb of East Melbourne. The project spans across three floors and a total of 87 m^2 and provides an example of how small areas within existing cities can be used to deal with a growing population and provide housing that is supported by existing infrastructure.

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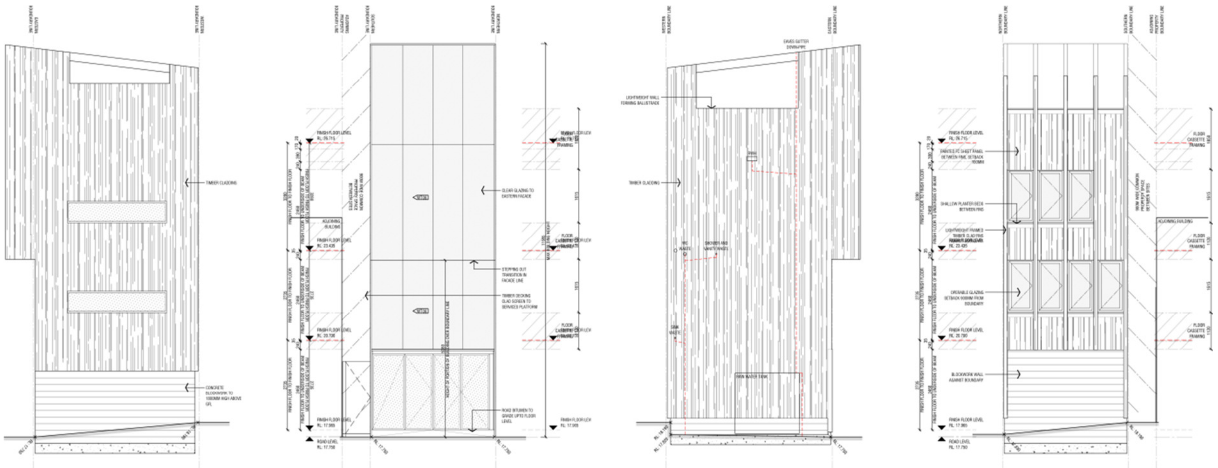

North East South West

Figure 1 Elevations of the 5x4 Project, Courtesy: Craig Chatman, Architect

Life cycle energy assessment and optimisation

This section outlines the approach taken to assess and optimise the life cycle energy demand associated with the 5x4 project. A range of construction assemblies were selected based on optimised thermal performance and a selection of standard and low impact materials. Eleven different floor assembly variations and 52 different wall assembly variations were considered. The energy associated with the initial construction, operation, maintenance and refurbishment of the assemblies over a period of 100 years was assessed.

Embodied energy

Optimisation of embodied energy for the 5x4 project was an iterative process. The aim was to select construction assemblies for the building that resulted in minimal life cycle embodied energy requirements (initial and recurrent). A list of floor and wall assemblies was compiled based on currently available materials as well as the design team's knowledge of the types of assemblies that would offer the best opportunities for minimising operational energy demand.

The initial and recurrent embodied energy of each assembly was then assessed, assuming a building life of 100 years. The results of this assessment were analysed by the project team, highlighting reasons for high embodied energy results as well as identifying materials with the highest and lowest life cycle embodied energy demand in order to further refine assembly selection and inform the development of the project's design. Once those assemblies with a comparatively high life cycle embodied energy demand were excluded, the final selection of assemblies was made. This selection was based on a range of environmental and non-environmental factors (i.e. thermal performance, material availability, cost, project suitability etc.). Hence, it is not necessarily the assembly with the lowest life cycle embodied energy that was chosen, but a balance was struck between a number of key factors.

The embodied energy of the assemblies was calculated based on the energy required to manufacture the individual construction materials. For this, a comprehensive hybrid embodied energy assessment approach was used. This approach uses national average statistics that model the financial flows between sectors of the economy, referred to as input–output (I–O) data, to fill the gaps in traditional process-based approaches caused by system boundary incompleteness [inter alia 8,9,10].

Process data were sourced from the SimaPro Australasian database for materials [11], giving quantities of energy required to manufacture a unit of material. The I–O data used was based on Australian I–O tables [12] and national energy accounts for Australia [13]. This data was combined to form hybrid material embodied energy coefficients.

Material quantities were determined for a 1 m^2 area of each assembly. The individual material quantities were multiplied by their respective embodied energy coefficient and summed to determine the initial embodied energy of each assembly. Recurrent embodied energy, accounting for the energy associated with manufacturing replacement materials over the 100-year estimated life of the project, was then determined. Average materials service life figures from a range of previous studies were used to estimate the embodied energy associated with the replacement of materials over the project's life. The estimated service life for some of the main materials used are provided in Crawford [14].

The recurrent embodied energy of each material was calculated based on its embodied energy coefficient and the quantity requiring replacement. The energy embodied in each material was then multiplied by the number of replacements for that material over the life of the project, and summed to determine the total recurrent embodied energy associated with the assembly. The exact number of replacements required for each material was determined by dividing the service life of the house (100 years), by the average service life of the material, subtracting 1 (representing the material used in initial construction at year zero) and rounding up to the nearest whole number (to reflect the fact that materials cannot be replaced in part).

It is acknowledged that the embodied energy coefficients associated with the replacement materials used over the life of the project will change over time due to factors such as improvements to manufacturing processes. However, for the purpose of this study it was assumed that the embodied energy coefficients would remain constant.

Operational energy

The predicted operational energy demand of the 5x4 project was determined utilising IES-VE software and average climatic data for Melbourne. A complete thermal dynamic model was developed that simulated the operational profile and performance of all the systems in the building. It accounted for the materials used in all the assemblies and the context in which the building is set. Numerous studies were completed to optimise the thermal properties of the building envelope, extent of opening windows and inclusion of phase change material to reduce the annual operational energy consumption.

An energy recovery ventilation system has been incorporated into the building for the periods in the year when the climate necessitates the building to be sealed (approximately 60% of the year). Whilst this consumes energy, the energy recovery in the air streams enables the house

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to be very well ventilated and maintain comfort conditions without heating or cooling. This results in significant energy savings compared to the current practice of air-conditioning.

Additional energy savings
In addition to the potential embodied and operational energy savings possible through the optimised design of the project, there are additional energy-related benefits associated with the project due to its location in an existing well-serviced area. An estimate of the energy savings due to a reduced reliance on private transport and new infrastructure has been made based on the approach developed by Stephan [15] and compared to the most common form of new housing in Melbourne – low density outer-suburban.

Results and Discussion
This section presents and discusses the results of the life cycle energy assessment and optimisation process for the 5x4 project. It also highlights some of the key findings that may help to inform the design of similar buildings in the future.

Embodied energy
The embodied energy of all 63 different assemblies considered is shown in Figure 2 and 4.

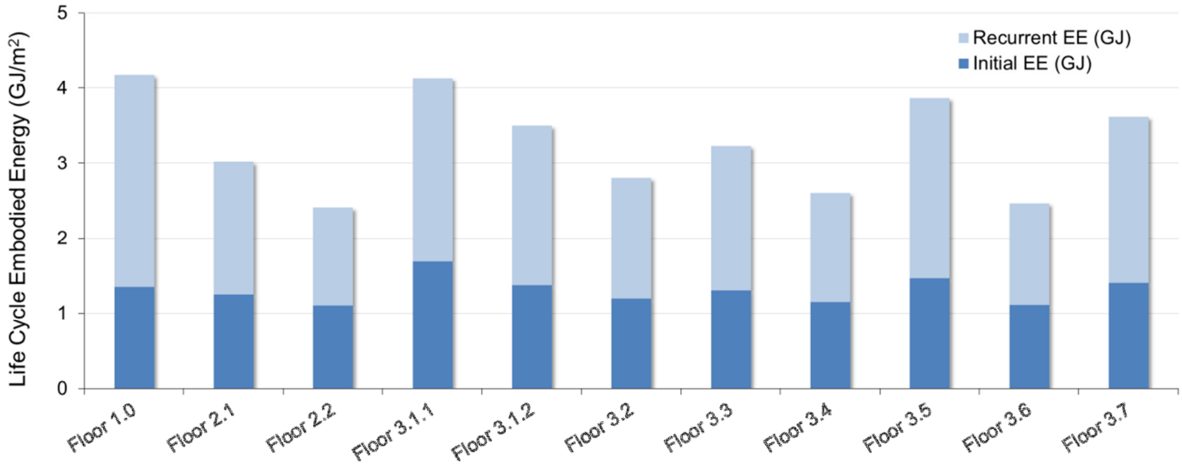

Figure 2 Initial and recurrent embodied energy of 11 floor assemblies

The assemblies with the lowest initial embodied energy tended to also be those with the lowest life cycle embodied energy. The floor assemblies found to have the highest life cycle embodied energy demand were those that used either frequently replaced items, such as carpet, or a more energy-intensive sound insulation material. Conversely, the assemblies with the lowest life cycle embodied energy demand (2.2, 3.4 and 3.6) were those that used less energy-intensive materials, required fewer replacements and included materials with a high recycled content. A breakdown by material for Floor Type 2.2 is shown in Figure 3.

The wall assemblies with highest life cycle embodied energy demand (Wall 4.0 – 6.8.3) are those consisting of double and triple glazing. Wall type 6 is a double-glazed spandrel panel with variations to internal lining and insulation types. For these assemblies, glazing represents at least 70% of their life cycle embodied energy demand. Avoiding the use of glazing in

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spandrel panels, where there are less energy-intensive alternatives for the equivalent function, can significantly reduce a building's embodied energy.

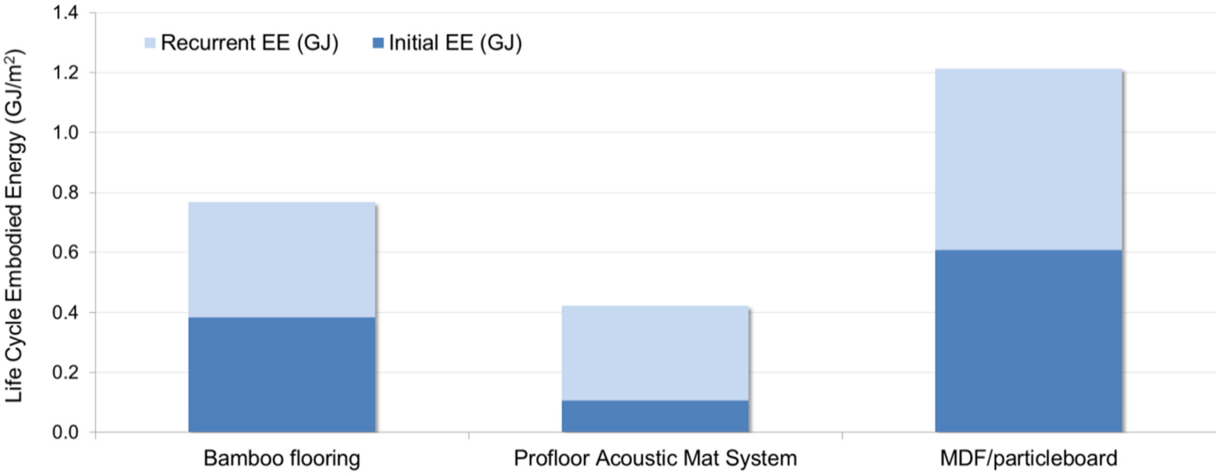

Figure 3 Initial and recurrent embodied energy of Floor Type 2.2, by material

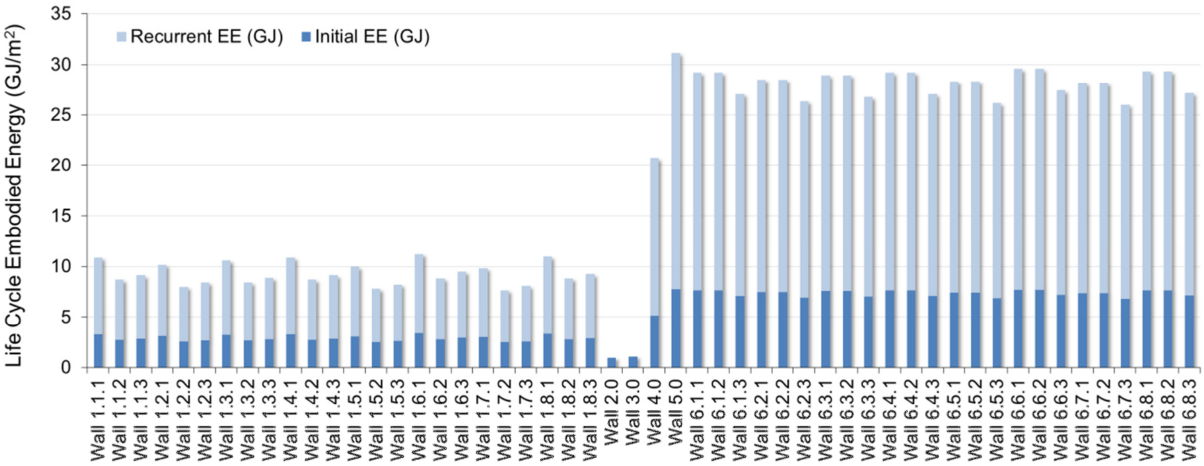

Figure 4 Initial and recurrent embodied energy of 52 wall assemblies

Fluctuations in embodied energy for Wall Type 1 relate to variations in internal and external linings and insulation types. Of the materials assessed, wool-based insulation, high recycled content internal linings and panellised timber external linings result in the lowest embodied energy demand. Wall Type 2 (concrete blockwork) and 3 (precast concrete) have no recurrent embodied energy due to an expected service life of at least 100 years. Operational energy demand is expected to be higher for these wall types due to a lack of additional insulation.

Operational energy

The breakdown of the predicted operational energy demand for the 5x4 house is shown in Figure 4. The total operational energy demand for the optimised building was found to be 38.5 kWh/m^2/annum. The nature of a building that can operate in both a fully sealed and naturally ventilated mode means that energy consumption is largely determined by occupant behaviour and weather. Predicting the energy demand is thus subject to large variation and

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significantly influenced by assumptions made in any calculation. For the purposes of benchmarking performances, the building has been simulated as a fully sealed building based on NaTHERS operational profiles and the performance specifications of all the equipment. In reality, we expect the building to never use cooling or heating when the windows and shading systems are used correctly by the occupant.

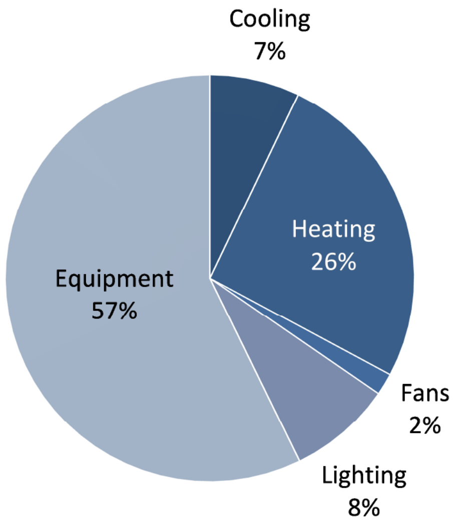

Figure 5 Annual predicted operational energy demand (fully sealed mode)

Additional energy savings

The total transport energy savings for the occupants of the house are estimated to be 9,738 GJ over 100 years. The combined direct (fuel/electricity) and indirect (embodied) transport energy requirement of the occupants of 7,902 GJ is significantly lower than the 17,640 GJ that is estimated to be required by an identical house in the outer-suburban areas of Melbourne. A greater use of public transport is the main reason for this energy saving.

The house's location in an established, well-serviced inner-suburban area is estimated to have saved 2,175 GJ over 100 years due to the avoidance of new infrastructure construction (roads, pipes etc.). The density of housing in this area also means that recurrent embodied energy for infrastructure maintenance is reduced on a per household and capita basis. Excluding the operational and embodied energy demands, as these are assumed to be identical for both locations, the inner-suburban house results in a 60% reduction in life cycle energy demand.

The initial life cycle energy analysis performed at assembly level provides a useful starting point to identify optimal materials and systems and provides useful information for designing similar projects. However, it is the combination of assemblies and systems that represents the basis of the eventual life cycle energy performance of a building. While beyond the scope of this initial study, the next phase will involve an analysis of the complete house. This will provide an opportunity to make any final adjustments to the energy performance of the project and provide a benchmark for future monitoring and performance comparisons.

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Conclusion

This analysis and the 5x4 project demonstrate the ability to significantly reduce the energy demand of housing as well as the need for comprehensive assessment techniques and a well-informed design process. The analysis of the results suggests that:

- Materials with a high recycled content are preferred as they tend to have a lower embodied energy compared to virgin material alternatives
- Material life needs to be considered as those with a low embodied energy but frequent replacement can result in higher life cycle embodied energy
- Solid timber products are preferred over manufactured/processed timber products
- The embodied energy of some insulation products can be significant
- The embodied energy of glass can be considerable and the need for double/triple glazing must be balanced with the level of thermal performance they can provide
- Double-glazed spandrel panels should be avoided
- Minimising energy embodied in a building's initial construction is critical as energy expended in the future (for replacement materials and building operation) is likely to be less carbon intensive than the energy presently being used in material production
- Considering the thermal performance of the building envelope in relation to the climatic variation in a year will determine an efficient balance between reducing peak loads and annual energy consumed.

However, the extent of energy savings and level of environmental performance achievable in our buildings are still very much limited by the currently available materials and systems and fuel sources used in material and product manufacture and transportation. They are also highly dependent on our individual living standards, housing expectations and personal preferences and behaviours. Figures presented will vary depending on a number of factors, not least the service life of the building and materials used. Also, the findings of this study assume that energy intensities for various transport modes, energy supply and industrial processes remain constant for the next 100 years, which is highly unlikely.

Acknowledgements

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Driving forces of energy-related behaviour in residential buildings

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Abstract: *For a realistic prediction of total energy use in buildings it is required to acquire a better understanding of how occupant behaviour influences building energy consumption. This requires a better understanding of the relevant driving factors of energy-related occupant behaviour, as well as a quantitative approach to describe energy-related occupant behaviour. The energy use of occupants in residential buildings can be grouped in the following categories: heating, cooling, ventilation and window operation, domestic hot water, electric appliances, lighting, and cooking. For these residential energy use categories the relevant types of occupant behaviour have been discussed. The typical categories for driving forces that can be distinguished are physical environment, building/installation characteristics, time, biological context, psychological context, and social context. The identified driving forces (including the statistical significance if known) have been listed in various tables throughout this paper. Usually several driving forces determine a specific energy-related behaviour. For example the frequency of taking a shower depends of biological, psychological and social driving forces.*

Keywords: real energy performance, occupant behaviour, energy modelling, performance

1. Introduction

Energy use in residential and office buildings is influenced by the behaviour of occupants in various ways. Energy-related occupant behaviour, as meant here, is related to building control actions (in order to control the indoor environmental quality) as well as household or other activities. These actions and activities may be driven by various factors. The influence of occupant behaviour on energy use in buildings has been investigated in various domains: natural sciences, social sciences as well as economics. Many investigations in the natural science literature focus on (statistical) relations between energy-related behaviour and mainly physical factors influencing this behaviour, such as outdoor temperature, indoor temperature and solar radiation, see e.g. Refs. [i], [ii]. However, there is no well-defined relation between physical parameters and actions of control, e.g. outdoor temperature and window opening. In reality the occupant decides to open or close a window. This decision is based on a number of influencing factors that can be divided in physical environmental aspects, human biological aspects, psychological aspects and the interaction between occupants figure 1.

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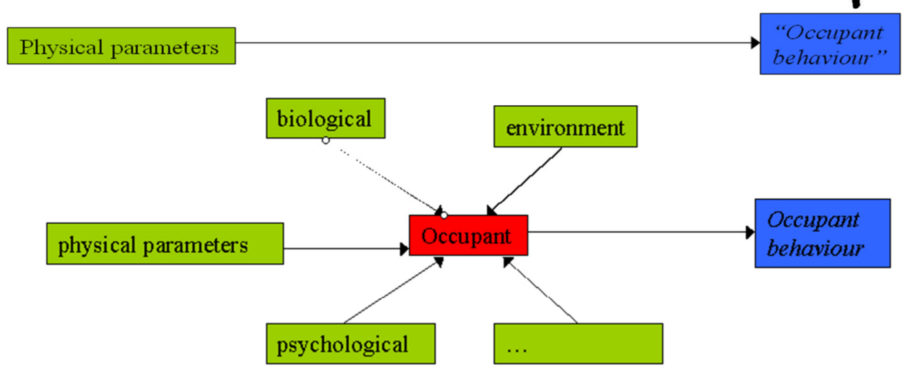

Figure1: Factors influencing occupant behaviour.

2. Definitions of residential energy-related occupant behaviour and driving forces

The complex relation between occupants and their environment is displayed in figure 2. This scheme is based on the presence of the occupant at a specific time at a specific location having access to specific building controls. The occupant experiences a specific physical environment due to location, biological and psychological states, and by the interaction with their environment.

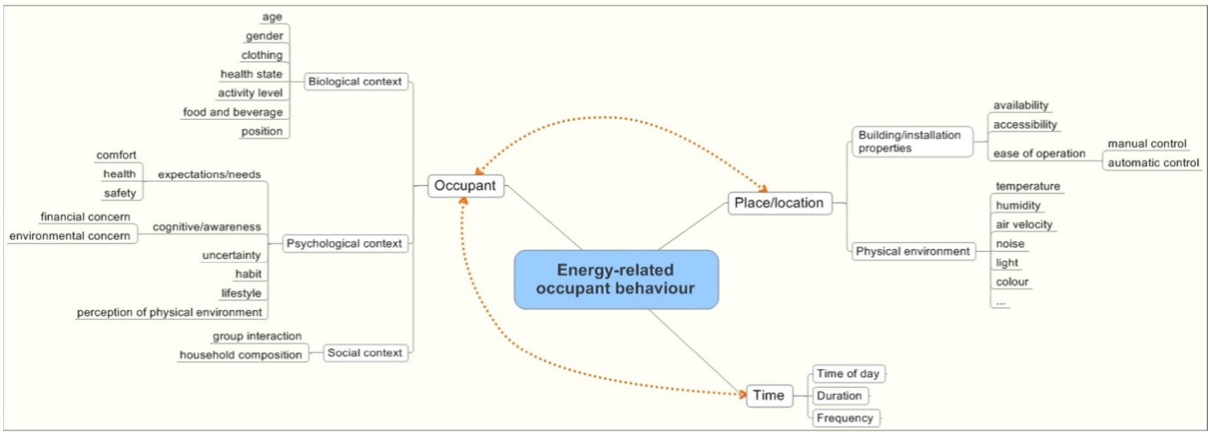

Figure2: Driving forces of energy-related occupant behaviour.

Information on occupant presence and activities may be obtained from time-use surveys. The interaction between humans and control systems of the building and installations results from a combination of *internal* and *external* driving forces (see e.g. Refs. [iii] and [iv]). The driving forces of energy-related occupant behaviour as shown in figure 2 are ordered according to the following categories: *biological context*, *psychological social context*, *time*, *building/installation properties*, and *physical environment*.

Another discussion on the relationship between humans and building and installations is given in Ref. [v]. The various research fields have different focus or requirements for occupant behaviour. In social or physiological science, the focus is on how occupant behaviour is formed and how they can be regulated. In natural (building) science more attention is paid to the quantitative description of occupant behaviour based of physical (*external*) parameters.

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The first three types of driving forces of energy-related behaviour depicted at the left-hand side of figure 2 (*biological context, psychological context, social context*), are *internal* driving forces of the occupant. These are being investigated in the domain of social sciences, economic sciences and biology. The *external* driving forces depicted at the right-hand side of figure 2 (*building/installation properties, physical environment*), are being investigated in the field of natural (or building) science.

There is a strong interaction between biological and psychological aspects, resulting in disciplines such as biopsychology or psychophysiology. Furthermore, regarding health there exists a model considering biological, psychological and social elements as a bio-psychosocial unit. Eating or drinking habits are strongly influenced by cultural aspects. Thus, a strict differentiation between these driving forces is not easy to handle. With respect to the energy-related topics heating, cooling, ventilation and window operation which are related to thermal comfort, there will be a short section on behavioural thermoregulation representing an interface between the biological, psychological and cultural context.

Biological context: age, gender, health situation, clothing, activity level, food and beverage.

Psychological context: Occupants tend to satisfy their needs concerning thermal comfort, visual comfort, acoustical comfort, health, safety, etc. Furthermore, occupants have certain expectations of e.g. the indoor environmental quality. Other examples of psychological driving forces are awareness (e.g. financial concern, environmental concern), cognitive resources (e.g. knowledge), habit, lifestyle, perception, emotions and self-efficacy (e.g. control of environment). Apart from autonomous biological processes there is a variety of deliberate regulation options. Adequate behavioural thermoregulation can be considered as a result of learning processes, experiences or as culturally driven.

Social context: Social driving forces refer to the interaction between occupants. For residential buildings this depends of the household composition.

Building/installation properties: insulation of buildings, orientation of façades, heating system type, thermostat type (e.g. manual or programmable), etc.

Physical environment: temperature, humidity, air velocity, noise, illumination, and indoor air quality.

Energy-related occupant behaviour, influenced by these driving forces can be usage-related, purchase-related, and maintenance-related. The types of energy-related occupant behaviour concern actions related to:

Heating: The activities of occupants have become more important within buildings with lower energy consumption. User behaviour and lifestyle can affect energy consumption by up to a factor of three, see Ref. [[vi]]. Occupant behaviour related to heating concerns temperature set point, number of heated rooms, heating duration, gender, age, expectations, knowledge of control function and meteorological conditions.

Cooling: Depending on the type of system, occupant behaviour has a significant influence on the use of cooling. From the general to the detailed, this starts in some cases with the choice of cooling system, the duration and frequency of usage, the choice of set-point temperatures and the frequency of maintenance.

Ventilation and window operation: Investigations on window opening behaviour and natural ventilation have mainly been carried out with two aims: to find whether or not occupants are provided with adequate fresh air and to find the influence on energy consumption. The former category of studies has usually been carried out in dwellings and has a health or a comfort perspective, while the latter category has mostly been studied in offices with a comfort and energy performance perspective. So far, there are only a few investigations regarding

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residential buildings and the studies that are aiming at implementing realistic behaviour patterns in simulation programs have been based on occupant behaviour in offices. No investigations regarding mechanical ventilation driving forces in residential buildings have been found in the literature.

Domestic hot water: Occupant behaviour can significantly influence the use of hot water in residential buildings. Examples of energy-related occupant behaviour related to domestic hot water use are the frequency of taking a shower, duration and intensity of showers; frequency of taking a bath; frequency of sink use; frequency and temperature of washing machines and dish washers, efficiency of water using appliances.

Electric appliances / lighting:

The use of electric appliances and lighting in residences is strongly influenced by occupant behaviour. When the energy consumptions for appliances and lighting are considered, large variations are found, which partly relates back to socio-economic parameters such as income, persons per household, age, education etc., but research regarding other ways to describe the occupant behaviour related to energy consumption is also on going, though a final and perfect model is way ahead of us at the moment. Another suggestion for understanding the occupants comes from social science, where the practices of the occupants are used as indicators for their energy consumption. This model is suggested by Ref. [vii]. It is based on practice theory where the routines, way of thinking and acting of the occupants makes the basis for different energy related behaviours varying from very energy consuming families to families who know how to save energy and also are very good at it. Routines are influenced by norms and ethics learned in childhood, by conscious reasoning on economic or ecological aspects, by design of new technologies and by changes in social relations.

Cooking:

For cooking purposes many different appliances can be used, such as microwave ovens, ovens, stoves, pressure cookers, kettles, etc. The type of equipment used and their corresponding energy consumption as well as the number of meals prepared will determine energy use for cooking. Only very limited information on driving forces for occupant behaviour related to cooking has been found in the literature.

Interactions between behaviour:

Occupant behaviour related to heating is not an isolated phenomenon, but rather a combination of driving forces that must be analysed in relation to each other. Ref. [vi] finds in Danish homes without mechanical ventilation, that heating behaviour is typically influenced by the combination of set-point temperature combined with window opening. A strong correlation was also found between window opening behaviour and indoor temperature set-point during the cold season, making it difficult to ascertain which influences which behaviour: indoor set-point temperature or degree of window opening. Similar to the findings in Ref. [vi] that occupants have established behavioural patterns that are not coupled with environmental factors, some interviewed occupants in a Viennese low energy cooperative also opened windows due to established morning and evening routines, as opposed to opening windows as a reaction to microclimate conditions. The time of day then becomes a driving factor, see Ref. [viii]. In Ref. [ix] multivariate regression models have been developed for window opening, fan usage and interactions with the sun shading device based on data from a semi-controlled climate chamber experiment in an office environment. They found that for the window opening behaviour, the fan state has a significant influence as well as vice-versa (the window state influencing the fan state). The usage of the sun shading device was influenced by the state of the window, but not by that of the fan. The state of the sun shading device did not have a statistically significant influence on the other two interactions. There are several

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studies dealing with the use of shading systems in office environments. Nevertheless, a literature review on the use of sun shading devices in the residential environment did not reveal a substantial amount of publications regarding the topic of user behaviour.

3. Definitions of energy-related occupant behaviour in office buildings

For office buildings the classification is at three different levels:

- individual occupant/manager level;
- zone/office level;
- building level,

At each level, occupant behaviour with respect to *lighting system*, *appliances*, *windows*, *ventilation*, *air handling units* and *water systems* is discussed in the report on occupant behaviour in office buildings.

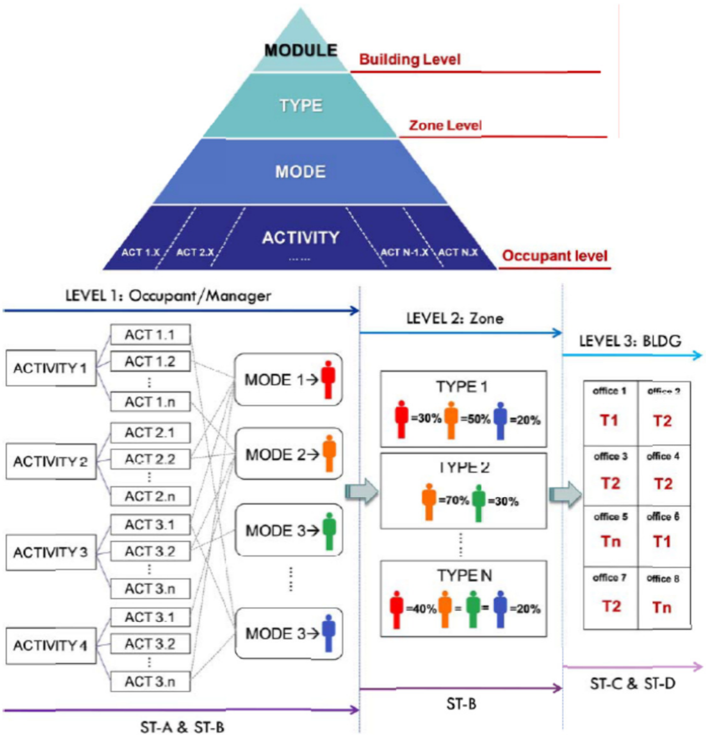

Figure 3: Methodology for occupant behaviour definitions in office buildings.

4. Modelling energy-related occupant behaviour

Occupant behaviour can affect the energy usage by a magnitude of 3 and above. A wide range of driving forces of energy-related behaviour was shown to have a significant influence – these were grouped into biological, psychological, social, time, physical parameters of the environment and the building. This demands interdisciplinary work between engineering and social sciences. But what is meant by behaviour? When it comes to interaction between buildings and human beings, a variety of disciplines is occupied in research on energy-related comfort parameters such as room temperature or indoor air quality. With respect to the energy-related issues of this report, by the term 'behaviour' is meant the following: observable actions or reactions of a person in response to external or internal stimuli respectively actions or reactions of a person to adapt to ambient environmental conditions such as temperature or indoor air quality or sunlight. In this definition attitudes and motives of a person which lead to a specific action are not included. With respect to the complexity of

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this issue, beside the models dealing with simulation of energy performance, some psychological models are presented, which show different approaches to explain behaviour as a result of decisions, attitudes and habits. Different energy-related behaviour patterns based on different environmental attitudes may play a role in the context of counselling, decision making concerning technical building systems or intervention strategies for households. Although there are no general differences in scientific principles between natural sciences and human sciences, the integration of different perspectives and vocabulary is not trivial. Nevertheless the goals are ambitious with respect to models at the interface between formalistic parameters and real life processes, especially when human behaviour is taken into account. Models are always a reduction of complexity and abstraction, at the same time it has to be guaranteed that all relevant parameters are considered, namely objective physical (environmental) parameters, personal variables and the interaction between these two sides. The models are translated into computer simulation as a connection of theory and experiment. This includes mathematic-logical processing, by which there might be the risk of overestimating the degree of precision respectively the explanatory power of results.
From the perspective of environmental psychology computer simulation is considered as a helpful method to look at complex systems and to handle practical problems, but the method is seldom applied, see Ref. [x]. Methodic determinism in the human sciences is often a basis for modelling human behaviour, assuming that adequate explanations and regularities of attitudes, intentions and behaviour can be found respectively assumed, but "A computer simulation does not necessarily guarantee that a theory is more consistent or comprehensible. Nor does a program's successful performance guarantee that the theory is generalizable, or even that the causes for the success are those predicted by the theory" , see Ref. [xi].
Computer simulation in the field of user behaviour and energy use can serve as an approach to circumstances and practical solutions by visualizing the processes in different energy-related settings. The models can be used as basis for calculation of expected energy consumptions as well as verification of theoretical assumptions about driving factors for energy-related behaviour. Beyond the calculation of energy consumption, the models could show the potential to face practical implications such as:

- the fit between building operation and user behaviour (match or mismatch);
- behaviour as basis for building optimization (under which conditions behaviour turns into counterproductive behaviour?);
- behaviour as a basis for interventions (e.g. information about the building concept, handling of controls as well as training for energy-related behaviour).

5. Purpose of modelling

On the most general level, two purposes of modelling occupant behaviour can be distinguished: (1) modelling occupant behaviour in order to understand driving forces for the behaviour itself, and (2) modelling the occupant behaviour in order to reveal its relationship to energy demand and usage and the driving forces for variations. Within the framework of this Annex, the second one is the major concern, while the first one might be necessary in order to gain deeper insides into the factors leading to variations in the relationship. An important question is how much into detail does one have to go to reach the set purpose. This is strongly dependent on the number of buildings, the user profile and the time scale. With respect to the number of buildings, a single object needs to be dealt with differently compared to multiple objects. The user profile can be made for a known user or unknown users and the time scale considered can be short term (daily, hourly down to fractions of seconds) or long term (season, year). The occupant behaviour can be modelled through schedules or diversity

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profiles (Type A), stochastic models (Type B), or agent based models (Type C). Table 1gives an overview of possible objectives for the simulation of occupant behaviour together with typical time scales, time steps and preferred behaviour models for single buildings and Table 2 for a group of buildings.

	Design			**Commissioning**		**Operation**
	Conceptual	Preliminary	Final	Initial	On-going	Control
Aim	design concept comparison	design optimization	system sizing/ building code compliance	initial commissioning	fault detection	model predictive control
Typical time scale	season, year	season, year	season, year	?	continuous	1 or 2 days ahead
Typical time step	1 hr.	1 hr.	1 hr.	1 min, 1 hr.	1 min, 1 hr.	1 min, 1 hr.
Preferred behaviour model	A	A, B or C*	A (B or C*)	A, B or C*	A, B or C*	A, B or C*
* The required model depends on the sensitivity of the investigated building performance indicator to occupant behaviour. This sensitivity depends on the performance indicator itself and on various building related aspects, among others, building function and user type, building/system concept and the degree of which the occupants are able to interact with the building, see Ref. [xii].						

Table 1 Objectives for the simulation of occupant behaviour, time scales and preferred behaviour models for a single building.

	Design			**Commissioning**		**Operation**
	Conceptual	Preliminary	Final	Initial	On-going	Control
Aim	policy making/ solar/shading analysis	solar/shading analysis	design electricity grid / district storage	?	fault detection of district storage	policy making/ solar/shading analysis
Typical time scale	season, year, 30-years	week, season, year	week, season, year		continuous	season, year, 30-years
Typical time step	1 hr.	1 min, 1 hr.	1 min, 1 hr.		1 hr.	1 hr.
Preferred behaviour model	A	A	A		A	A

Table 2. Objectives for the simulation of occupant behaviour, time scales and preferred behaviour models

An overview of additional factors influencing the choice of model is given in figure 4.

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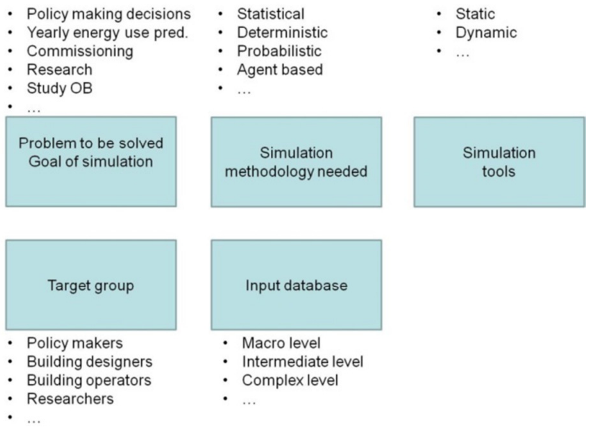

Figure 4: Overview of factors influencing model choice.

6. Model types:

Psychological models:

Psychological models of occupant behaviour can be grouped into those explaining the behaviour itself and those related to the energy use in buildings. Examples of the first are Theory of Planned Behaviour (Ref. [xiii]) and the MODE model (Ref. [xiv]). Examples of the second are the behavioural model of residential energy use (Ref. [xv]) and the NOA model (Ref. [xvi]).

Average value models:

Average value models are defining the important parameters for occupant behaviour which influences the total energy use of a building for a selected period (e.g. daily, weekly, or monthly basis). Empirical studies have shown that average values are sufficient for estimating the total energy use in cases of residential buildings with many inhabitants such as apartment buildings (Ref. [xvii]). The larger the building, the larger the sample set, and the deviation from the average becomes less with greater numbers of living units. Predicting total energy use for individual single family homes has shown to be more challenging. Energy use profiles for single houses can show great variance from current estimations based on average values (Ref. [xviii]).

Deterministic models:

Deterministic model are using predefined typologies of families, which will give deterministic input values for computer simulations. Building simulation tools, on the other hand, are based on heat transfer and thermodynamic equations, which are deterministic. Typically human (control) actions are modelled based on predefined fixed schedules or predefined rules. These tools often reproduce building dynamics using numerical approximations of equations modelling only deterministic behaviour. Often, occupant behaviour is not specifically addressed in simulation tools, but only modelled by means of its effect. E.g. the infiltration rate might be modelled as a fixed value that does not vary over time. However, in reality an occupant will not react in exactly the same manner every time he is exposed to the same condition. Consequently, occupant behaviour will include elements of randomness.

Probabilistic models:

Traditional modelling approaches look at human beings as if they would behave in a fully deterministic way. However, in the real world many parameters influencing the environmental conditions and occupant behaviour (e.g. actions to control indoor environmental parameters) can vary significantly and unpredictably during the building life. The evaluation of occupant behaviour will be based not only on fixed actions, but on coupling these repeatable interactions with building control systems with a certain probability. This approach results in a probability distribution instead of a single for energy use.

Agent-based models:

Agent based modelling is based on a bottom up approach. It focusses on individual behaviour and local interactions. Simple behaviours at a micro-level will result in complex behaviours at a macro-level. The agents may be very different objects varying from individual human beings to components of energy networks. Agent based models are modelling occupants as individuals with autonomous decisions based on rules and experiences (memory, self-learning). Agent-based simulation models are being used to quantitatively study multi-agent systems, in which agents are autonomous as well as interacting with each other and the environment.

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Session 118:

Towards a shared definition of nZEB? (II)

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Evaluating the Viability of Net Positive Carbon Sequestration in Buildings based on a Case Study in Brisbane, Australia

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Abstract: *Developed nations must begin transitioning their economies towards reversing greenhouse gas emissions in order to prevent further climate disruption. As currently designed, cities are a major contributor to emissions. Net Positive Development (PD) theory provides a framework for planning and designing cities to support their regions rather than depleting them. A design for Brisbane, Australia, was undertaken to test whether a building can sequester more carbon than it emits by exceeding resource autonomy and using extensive building integrated vegetation. A full life cycle approach showed that net positive carbon sequestration (as one key PD element) is theoretically possible. This paper provides evidence that net positive building carbon performance can also be economically viable in Australia, depending on location and user profile. Designed as an integral part of nature, architecture can become a climate mitigation strategy that increases life quality and natural security at net savings to society.*

Net positive design, carbon equivalence, payback time, ecosystem services

1. Introduction

Current global greenhouse gas emission levels already exceed the 1.5° C or 2° C targets for 2020 and are still increasing (1). The Earth's carrying capacity has also been exceded. In 2007, the human global ecological footprint reached 1.5 (2). Developed countries use far more than their fair share. For example, Australia's ecological footprint is 6.6 global hectares per person. If all countries consumed this amount of resources, it would take the biocapacity of three Earths to support their lifestyle (2). The long-term consequences are significant. According to the Intergovernmental Panel on Climate Change (IPCC), "a large fraction of anthropogenic climate change resulting from CO_2 emissions is irreversible on a multi-century to millennial time scale, except in the case of a large *net removal* of CO_2 from the atmosphere over a sustained period" (3). This means that more CO_2 must be *removed* from the atmosphere than *added*. Although cities occupy only two per cent of the Earth's surface, they use 75 per cent of its resources (4). Since cities are responsible for a major part of emissions, they must become a major part of the solution. However, current best practice planning and design strategies are not enough to mitigate climate change, as these only aim at reducing emissions relative to business as usual.

A growing number of professionals in building research and practice are beginning to adopt the paradigm shift from the prevalent linear-reductionist to an ecological worldview, as called for by the sustainability movement over the last decades (5; 6). Regenerative development was first introduced in the late 1970's by John T. Lyle. The regenerative paradigm enables a co-evolutionary partnership with nature based on strategies of adaptation, resilience and regeneration (7; 8). Net Positive Development suggests that it is necessary to go beyond zero and create buildings that 'give back more than they take' by (in short) increasing the ecological base (eg. ecological carrying capacity, ecosystem services, ecosystem diversity, etc.) and public estate (eg. access to means of survival and wellbeing) - relative to escalating biodiversity losses, disparities of wealth and consumption (9).

Net positive planning strategies include many complex dimensions such as social and cultural aspects and the health of humans and ecological systems. This research focused on one key PD element by quantifying the carbon sequestration of a sustainable building design for Brisbane, Australia. While not capturing specific ecological values, 'carbon equivalence' measures some factors of both energy and the ecology. A brief outline of the case study, including life cycle energy, water and carbon quantification, was presented at 'Pushing the Boundaries - Net Positive Buildings' at SB13 Vancouver (10). Subsequently, the full paper documenting the case study and detailed measurement method was submitted for the Special Issue 'Net Positive Design' of Building Research & Information (BRI). Further work was undertaken on economic viability of a 'beyond zero carbon' approach, which is discussed here.

On the global scale, long-term emission reduction is critical to avoid further environmental degradation and associated costs of inaction (11). While promising technologies may soon be available for carbon dioxide capture and storage (e.g.12), their application is dependent on transportation limits of minerals. Further, these technologies are associated with high immediate public investment costs. This could be greatly reduced by designing carbon neutral buildings or beyond with integrated vegetation as natural carbon sinks, without increasing the project budget. Carbon mineral sequestration in building materials may be an opportunity, however this is not yet commercially available (13).

2. Studies in colder climates

The last decades have shown a growing trend toward 'net-zero' or 'carbon neutral' buildings. Clear systems boundaries, baseline conditions, timeframes etc. need to be defined (10; 14). Regenerative and net positive design strategies offer opportunities to transform conventional green building methods by providing whole systems solutions that respond to climate variables, population growth and associated global challenges. Some inspiring projects in different climates were presented in the eco-positive stream at SB13 Vancouver (15), which aim to improve health and productivity of the occupants and provide social and educational values. These projects claim net zero in measurable factors such as energy, water or carbon, with the future goal to optimize their systems toward net positive contributions (16; 17). For example, a building in a sustainably managed Canadian forest of 80 hectares could even achieve net positive carbon sequestration (18). These concepts and case studies suggest that buildings could contribute as functioning parts of living ecosystems. To be net positive, design concepts need to be scaled up to the urban and regional level to maximise synergies across traditional site boundaries (19). This requires new forms of assessment and measurement (20).

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3. Case Study in Brisbane, Australia

A building design of an Interpretive Centre for net Positive Development in subtropical Queensland was used to test the PD concept by sequestering more carbon than it emits. It proposes a modular system, consisting of a series of inner buildings and atriums which are connected with a organic shaped space frame construction, creating landscaped areas for multi-functional use. The history of the site was investigated and a PD Ecological Transformation analysis performed to determine indigenous ecological conditions as a benchmark measurement, and to inspire the design. The building was designed to exceed resource autonomy in energy production, water and waste treatment as well as to support extensive building integrated vegetation. With substantial multi-disciplinary expert support, a full life cycle assessment of energy, water and carbon impacts was conducted (10).

It was found that a net positive carbon performance over the entire life cycle would theoretically be possible. The baseline for the design performance was set at 'zero operational carbon'. The amortization time for the building to pay back its embodied energy during its life cycle was determined *by surplus contributions only* from renewable energy systems and carbon sequestration by biomass. Carbon equivalence was used as environmental indicator to determine both positive (-CO_2e) and negative impacts (+CO_2e) of the development. It is important to emphasize that units of inert resources cannot represent the full value of living things or serve as surrogates for the ecology. However, they provide a uniform database for comparing different impacts from positive as well as negative sources numerically. In the final evaluation, cumulative impacts over the building life cycle were overlayed on a diagram to determine the 'Carbon Amortization Point' and potential surplus (net positive) gains from renewable energy and biomass sequestration. The calculations were based upon a 'best estimate'. It is suggested to include a contingency for uncertainties in the final evaluation.

The following categories were considered:

Negative impacts:

- 'Cradle to construction' LCA performed in Building Information Modeling (BIM) based collaboration, software used: Revit Architecture, LCADesign
- Embodied energy services and finishes: percentage of embodied energy
- Embodied energy photovoltaic system: estimate as per current scientific consensus
- Operational energy and carbon impact estimate: location specific greenhouse gas reverse calculation tool NABERS (21), no simulation or energy modeling

Positive impacts:

- Energy gains PV system (115 per cent of operational energy)
- Carbon sequestration in biomass (10.5 per cent of operational energy emissions)

Exclusions:

- CO_2 sequestration in soil due to various location specific variables
- CO_2 sequestration in timber based building materials as these cannot be directly controlled by the project team

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Embodied versus operational energy

The operating energy was minimized through eco-positive design, which resulted in a 40 per cent reduction compared to a conventional energy efficient building in Australia with a 5 star NABERS rating, as determined by the specialist environmental design consultancy WSP Built Ecology. The entire available roof area (less construction area) was used for a photovoltaic system of 690 kW which made a 15 per cent surplus to the estimated operational energy possible. Since a large proportion of the operating energy could be eliminated through passive and net positive design strategies and the remainder provided by renewable sources, the embodied energy became a larger factor. A 'cradle to construction' LCA was performed in BIM based collaboration to determine the negative impacts for envelope, structure, site work and construction. Studies have shown that an additional 24 per cent need to be allocated to services and 13 per cent to finishes which was added accordingly (14, Figure 1), reduced by 12 per cent for the services due to biophysical design.

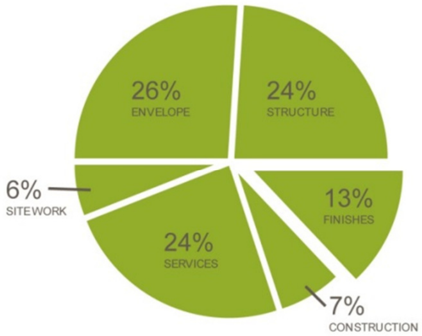

Figure 1 - Average initial embodied energy of an office building. Source: Cole & Kernan study (1996)

In addition, the PV system size necessary to exceed resource autonomy resulted in a large amount of embodied energy. Studies estimating the embodied energy of PV systems range between one and four years (22). A significant improvement has already been achieved in the last few years, and the technology is further rapidly advancing. It is expected that the embodied energy of PV systems will continue to decrease significantly over the next decade (23). Although PV systems themselves pay their embodied energy back within a couple of years, usually this only results in a reduction of operational energy. By exceeding energy autonomy and including both embodied and operational energy in the equation, it became apparent that the true payback period for the embodied energy of the building integrated PV's through 15 per cent surplus alone would result in an amortization time of 30 years because the building as a whole needs to cater for the much larger operational energy expense.

Recurring embodied energy over the life cycle

Very few studies indicate numbers for a full life cycle approach, but for a typical building with a 50 year life, the recurring embodied energy including fitout, services and finishes may equal the initial embodied energy of the building (14). In order to minimize this impact, it is therefore of increased importance to design for longevity, adaptability and reuse. Multi-criteria eco-labeling systems are available which assist in selecting eco-efficient products (24). The case study provides a surplus after amortization of embodied energy during the life

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cycle to offset recurring embodied energy. Fitout and renovations were not quantified in this project, however the largest unavoidable component of recurring embodied energy (and cost) in developed countries occurs after approximately 25 years through services replacement.

Carbon sequestration in biomass
Carbon sequestration through vegetation was assessed in collaboration with a horticultural scientist. The extensive building integrated vegetation would sequester an amount of carbon equal to 10.5 per cent of the emissions caused by the estimated operational energy. Vertical green spaces provide an opportunity for increased biomass production where limited space is available such as in cities. It was found in this study that with sufficient light in a vertical plane, biomass production can at least be doubled compared to the horizontal plane.

Net positive carbon performance
The results show that it is important to design for maximized energy efficiency in order reduce active technology and minimize embodied energy as this is the main energy factor for buildings which exceed energy autonomy during operation. In the case study in Brisbane, 15 per cent surplus from PV's plus 10.5 per cent through biomass sequestration meant the embodied energy could be amortized in 19 years. By adding an additional 15 per cent PV surplus, the amortization could be achieved after only 13 years. This means that the percentage by which the design is energy positive (ie. exceeds energy used) contributes significantly to achieving net positive carbon sequestration earlier in the life cycle. Although the size of the PV system accounts for a large amount of embodied energy, the offset from the surplus during operation far outweighs the initial impact. Therefore recommendation resulting from this research is that projects should aim to exceed energy autonomy through renewables by at least 30 per cent. Additional carbon credits could be purchased, however it was decided to only quantify contributions on site that are related directly to the design, not governmental incentives. The benchmark for carbon amortization could, for example, be set at 12.5 years in order to ensure net positive contributions which exceed recurring embodied energy.

System boundaries
Life cycle impacts of embodied and operational energy (from renewable systems outside of sunshine hours) are difficult to define because they require consideration of factors such as electricity generation, conversion and transmission. A system-based approach is critical to achieve high quality distribution, generation and consumption performance (25). Off-site quantifications were not performed in this study, but uncertainty could be addressed by on-site measures such as micro turbine wind power. The immediate on-site use is also vital for economic viability in Australia under current circumstances because suppliers still impose conditions on export of renewable energy to the grid. Despite rapid advances in technology, it will become increasingly important to assess not only the carbon performance of individual buildings but also consider the neighbourhood context in design and building regulations and transition to decentralized service structures. Carbon is only one PD criteria, but this case study indicates opportunities for creating synergies across traditional site boundaries to regenerate the region through net positive contributions.

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4. Economic viability of net positive carbon performance
The most efficient way to reduce costs and environmental impacts in construction or renovation is in the preliminary design stage which can predetermine 90 per cent of impacts (26). In this project, these strategies included maximal passive design, environmental control functions, multi-functional spaces and minimal active technology. Only a small proportion of the Interpretive Centre (conference centre and laboratories) were designed for mixed-mode air conditioning. Compared to a conventional energy efficient building, the 40 per cent reduction in operational energy would result in an immediate economic advantage. The modular design enables further cost savings during construction and operation. In addition, as in the case of many green buildings, there are additional economic benefits such as improved health and safety, reputation, employee satisfaction, increased productivity and reduced sick leave. In particular, two main factors were considered which distinguish a building with a net positive carbon performance from a conventional building:

a) Exceeding resource autonomy in operational energy production results in a large amount of additional embodied energy and initial capital expenditure. However, at the location in Brisbane and with the user profile of the case study, the financial payback period of a 690 kW PV system would only be approximately 7 years in a conservative estimate by WSP Built Ecology (Figure 2), and larger systems shorten the payback period.

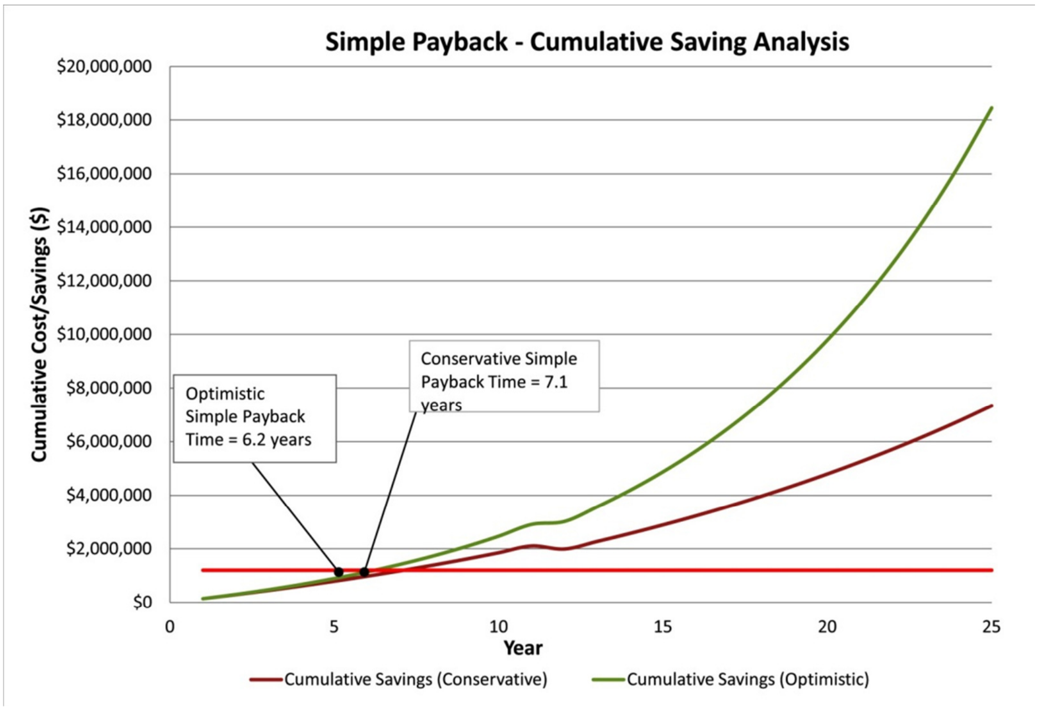

Figure 2 - Payback time 690kW Photovoltaic System, Bowen Hills, Brisbane, WSP Built Ecology, May 2014

This is in particular attractive for investors, as financing options are available with a neutral or positive cashflow (27). While the profitability is dependent on the location and individually negotiated contract with the retailer, the local use of the by PV generated electricity over seven days in the week is of advantage because economic disadvantages for export to the grid from the electricity supplier can be avoided. As a result, the financial payback would occur even earlier in the life cycle than the amortization of embodied energy. Even if the system would have to be replaced after 25 years, there would still be a net financial gain over approximately 2/3rd of its lifetime. Advanced technology in the near future and continuously rising electricity prices would result in a further improved business case. Australia's ideal sunshine conditions are currently still largely unused and network upgrades are required to provide the capacity for larger renewable systems. However, the 'Zero Carbon Australia 2020 Stationary Energy Plan' shows on the larger scale that it is technically feasible and affordable to replace all fossil fuel electricity with 100% renewable energy within 10 years (28).

b) Extensive building integrated vegetation

This provides a range of benefits on the physical, cultural and psychological level (29; 30) in addition to carbon sequestration. Much work has been done on quantifying ecosystem services in economic terms since 1997, when it was shown that they exceeded the value of GDP globally (31). More recently, scientists are estimating their ecological value for purposes of biodiversity offsetting and other trading schemes (32). However, many benefits, such as improved worker productivity and reduced sick leave are now being quantified (33; 34). While economic benefits are directly quantifiable for renewable energy gains and are likely to increase significantly in the future due to rising electricity prices, ecosystem services provide an asset which is often undervalued. Even if surplus gains from the photovoltaic system alone could offset the carbon emissions from embodied energy, this would not compensate for ecological degradation. It is therefore critical to include the ecology in building design and assessment (10). If we continue to decrease the Earth's life support system, climate change consequences will lead to exponentially higher cost for reparation.

Future activities and support of public entities toward PD in Australia

A demonstration building is the next goal in this research. The Australian Green Development Forum (AGDF) (35) adopted Positive Development in Lieu of Sustainable Development. The organization is facilitating several proposals for demonstration projects in Australia. Openings for future research are the inclusion of building fitout, recurring embodied energy, sequestration in building materials and soil, different renewable energy systems with regards to net positive carbon sequestration, social and ecological factors concerning PD as well as business case development and other strategies to facilitate the implementation in practice.

5. Summary / conclusion

Net positive design creates an opportunity to reverse the impact of the built environment to the natural environment in order to address current global challenges associated with accelerating population and consumption. The theoretical case study on net positive design in Brisbane provided quantified results which suggest that net positive carbon sequestration on the building scale is achievable and viable from an investment return point of view, and it can even be more economical than fossil fuel based solutions. A demonstration building is required to confirm these theoretical findings. Additional factors such as improved health and worker productivity are only measurable during building occupation.

Although not capturing specific ecological values, 'carbon equivalence' measures some factors of both energy and ecology. However, a clear baseline is needed to evaluate net positive carbon performance. Embodied energy becomes of increased importance once operational energy autonomy is exceeded. It is therefore important to design for natural materials, modularity, adaptability and reversibility. With minimized operational energy, less technology is required, which in turn reduces embodied energy. This means that net positive carbon sequestration can be achieved earlier in the life cycle as capital and operational cost can simultaneously be reduced. Applying net positive carbon sequestration strategies to the built environment provides an opportunity for multi-disciplinary and international collaboration. In particular, the application in emerging and developing countries could contribute to global emission prevention.

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Strategies to achieve deeper carbon reduction targets

Speakers:
Skopek J,

JLL, Toronto, Canada

Abstract: *Most existing buildings have the potential to achieve 30% energy savings, yet traditional energy programs typically produce energy savings in the order of 10-15%. This is not good enough, if we are to meet the 30-50% targets required to reduce carbon levels and mitigate climate change. There is no lack of methodologies or sophisticated technologies. Savings can come from three sources: more efficient systems and equipment, tenant/occupant engagement and improved management and operation.*

There are several challenges to meeting the carbon reduction targets, including deploying solutions in the mainstream. While no single approach can be effective on its own, a combination of methodologies and technologies is key.

Keywords, Sustainable retrofit, smart building, energy monitoring and continuous commissioning

Introduction

It is now widely recognized that the only way to combat climate change is through significant carbon reductions. For decades, the European Union has been at the forefront of that process, with proposals for carbon dioxide emissions to be cut by 40 percent by 2030. While the Americas and Asia governments have been dragging their feet, there is, nevertheless a growing groundswell of bottom-up action. An example of this is the 2030 Districts Initiative in approximately 12 cities in North America, whose goal is to reduce average building carbon emissions, energy use intensity, water consumption, and commuter transportation emissions in office districts by 50% by 2030 [1].

These carbon reduction goals of 40 to 50%, which are needed to ensure the health of the ecosystems and human survival, are lofty targets. While there are individual examples of projects that have achieved significant energy savings, most of the current large scale energy and sustainability programs produce energy savings and carbon reductions in the order of 10% to 15%.

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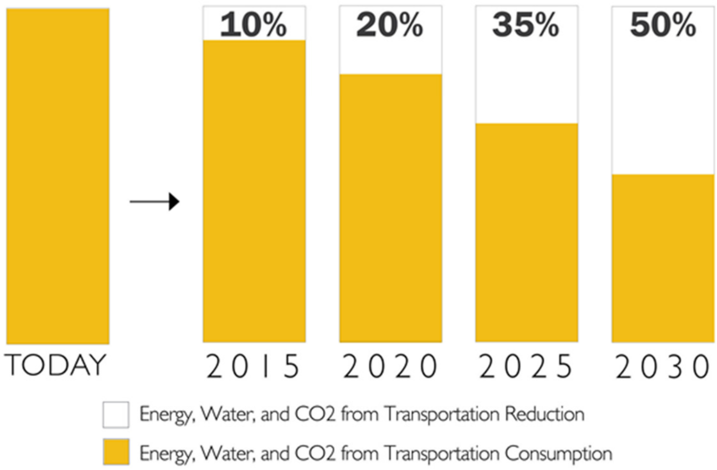

Figure 1-2030 Districts- Existing Building District-Wide Goals

For example, one of the most successful existing building programs in Canada –BOMA BESt, which uses the Green Globes methodology to benchmark energy and sustainability of existing buildings, is finding energy reductions of about 10% in the buildings that are being re-certified [2]. While not insignificant, these reductions are simply not enough to meet the targets of 40-50% required to combat climate change.

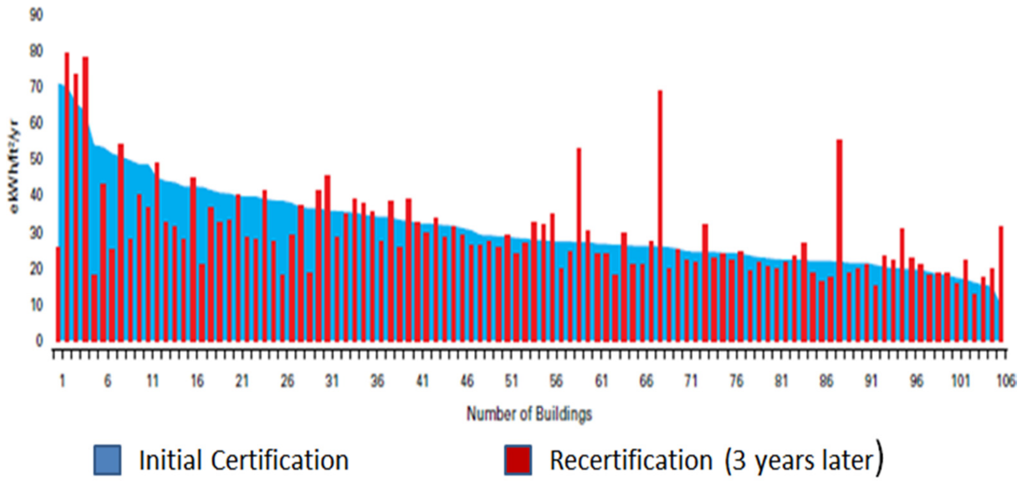

Figure 2-BOMA BESt – Reduced energy use intensity of 10% in re-certified buildings in 2012

And yet, most existing buildings do have the potential to achieve 30% energy savings. These savings can come from three sources: i) more efficient systems and equipment, which can contribute approximately 40% of the savings, ii) improved management and operations (another 40%) and iii) occupants/tenant engagement (20%).

More efficient systems and equipment - Integrated Energy Retrofit

The best approach to improving the efficiency of the systems and equipment is Integrated Energy Retrofit (IER). The traditional decision-making process for capital improvements has typically consisted of an audit, followed by improvement recommendations, where each recommendation is evaluated individually on the basis of its cost and payback. Integrated Energy Retrofit, on the other hand, uses a whole-building approach, in which a package of measures produces overall savings that are greater than the sum of parts. For example the Empire State Building retrofit used a bundle of measures including window and air handlers replacements , radiators insulation and tenant energy management measures, which together had implications for the HVAC strategy – in particular, decisions regarding chiller replacement. For example, using this integrated energy retrofit process, the Empire State Building achieved 38% energy savings, with a net present value investment that balanced carbon reductions with financial returns [3].

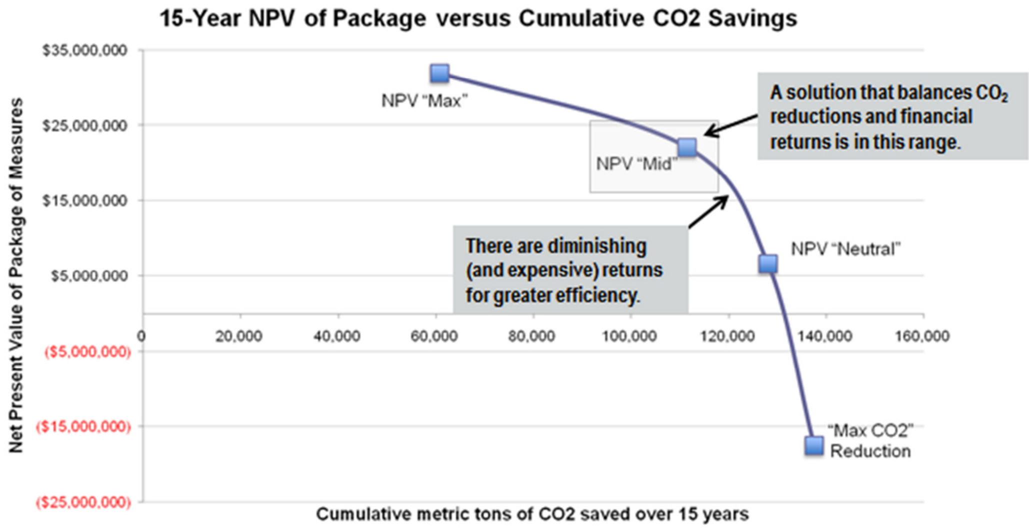

Figure 3-Integrated Energy Retrofit can achieve a high level of CO_2 and energy reduction cost-effectively-Empire State Building

To reduce energy, engage the people who use it

With the increase of plug load in buildings, tenant engagement and occupant behavior can also have an impact on energy. Occupancy conditions and practices include more efficient use of space, plug load and demand response. Measures include daylight and occupancy sensors for lighting, desktop smart power strips to reduce plug load, demand-controlled ventilation, cloud computing, a review of server rooms air distribution and temperature set points, blinds on windows to reduce heat gain during the cooling season and night-time heat loss during the heating season. Using measures such as these, Skanska, a multinational construction company, which relocated its U.S. headquarters to the Empire State Building, surpassed the building's efficiency standards and reduced its energy consumption by 57 percent compared to its previous space in another building, achieving an estimated $500,000 in energy savings over the life of the lease, and a payback of its initial 4.7% incremental investment within five years.

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Tenant sub-metering and a green leases also provide a framework that encourages conservation and ensures that the tenants benefit from any energy upgrades that they make in their leased space. Many studies also posit the added benefit of "greening the workplace" in terms of productivity improvements – for example, office layouts which allow daylight to penetrate deep into the space, and workplace which has effective thermal and ventilation controls. Another way to motivate tenants is by engaging them through their own corporate social responsibility policies. There tends to be a positive impact on employee morale, productivity and retention in companies whose senior management care deeply about sustainability, and which have dynamic green teams with effective workplace energy and sustainability campaigns. One online tool that is being used by several global corporations with large portfolios of leased space is *Green+Productive Workplace™* [4].. It provides green tenant performance metrics for energy, water, waste management, use of resources and commuting, as well as a wide range of productivity factors including indoor air quality, acoustics, visual and thermal comfort, and features, amenities and policies that impact employee wellbeing and work-life balance. The tool provides industry comparisons as well as orders of magnitude of potential energy savings and productivity gains that would result from making certain improvements in the workplace.

Building operations and smart building technology offer the greatest savings potential

While deep retrofits and tenant engagement play a significant role, the area which offers the greatest potential to reduce energy consumption at the lowest cost is to be found in the operation and management of buildings. An analysis of BOMA BESt data shows that management and operations have a greater influence on energy performance than efficiency features.

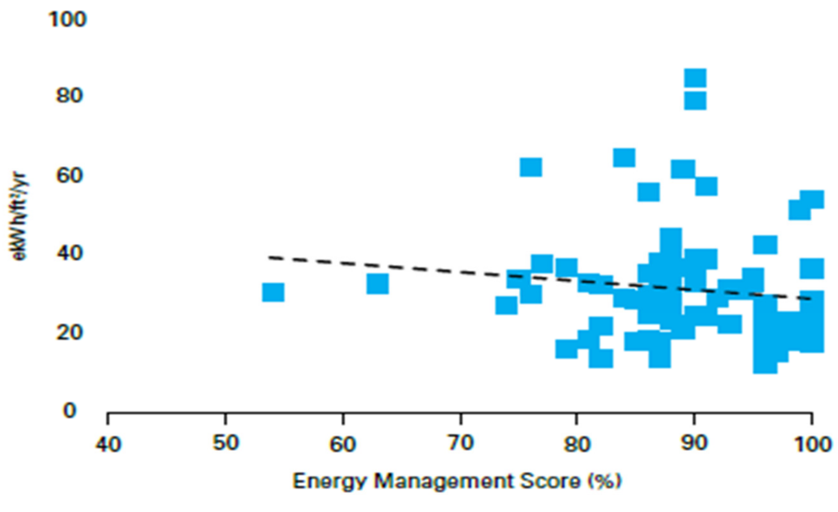

Figure 4-Energy Management Score and Energy Use Intensity in BOMA BESt Certified Office Buildings

This supports the findings of an Energy Star Portfolio Manager Study, "Building Performance Defined", which comments that buildings which have similar equipment can often perform quite differently. "This finding", says the study, "…challenges a longstanding misconception that building efficiency can be defined by the presence of efficient equipment."

While energy-efficient equipment can significantly contribute to whole-building performance, this can be a double-edged sword. This is because so-called "energy efficient equipment", if it is not being properly operated - can often be a primary source of energy inefficiency" [5]. Other studies quoted by the US Environmental Protection Agency support this assertion: Lawrence Berkeley National Labs found that in a sample of 60 buildings, half had system control problems, 40% had HVAC equipment problems, and 25% had economizers, and/or VSDs that were not functioning properly [6]. Another ESource study estimates that economizers have failure rates of 50% and higher. As a result, more energy was wasted from poorly running equipment than would have been saved if the equipment had been working properly. [7]

Smart Buildings – ongoing commissioning solution

Fortunately, smart building technologies can help to eliminate such inefficiencies. The ongoing stream of data from pulse meters and sensor points is monitored, aggregated, normalized, and then analyzed in real time, applying data analytics. If equipment is found to be functioning below optimum efficiency, notification occurs via an alarm system and/or a user- friendly dashboard portal. In addition, expert analysis can be also carried out by remote expert building engineers, who monitor the data and either provide on-demand support to an on-site building management team, or carry out the corrective and predictive maintenance remotely.

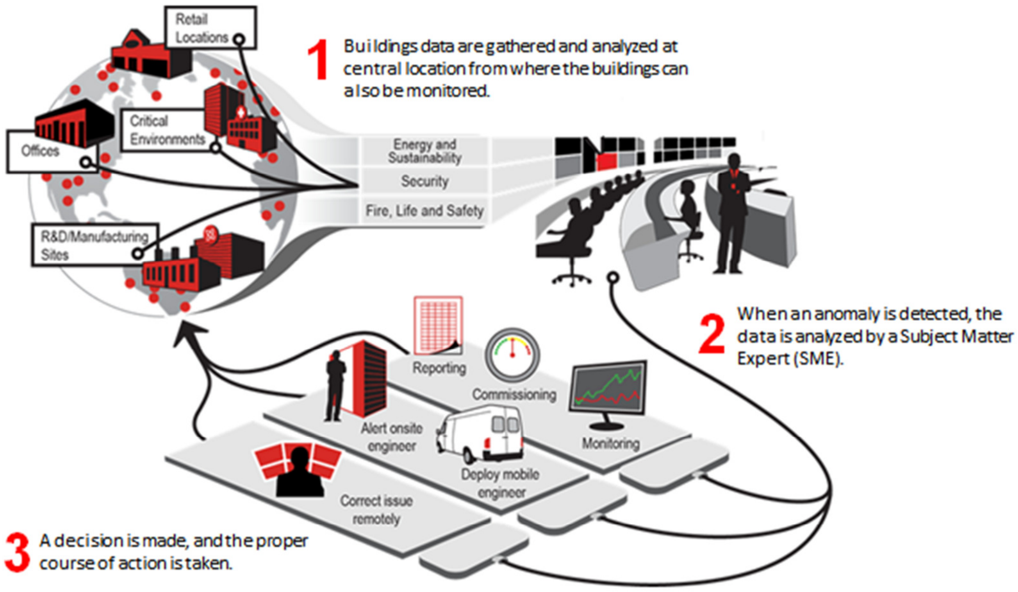

Figure 5-Ongoing (Monitoring) Based Commissioning

Smart building technologies come in a range of complexity depending on their size and functions. For smaller buildings such as retail, this may consist of just a smart controller with wireless real-time monitoring and control over the web built into a rooftop unit. Smart building technology also ties into tenant engagement, for the information on a building's performance can extend to the building occupants, thereby influencing their behavior.

The opportunities afforded by smart systems are enormous. For example Procter &Gamble deployed IntelliCommand™, an energy monitoring and ongoing commissioning systems, across 12 buildings totalling 3.2 million square feet of real estate, including their global headquarters campus in Cincinnati; and numerous laboratories and manufacturing operations [8]. The combination of cloud-based, smart-building continuous commissioning and performance adjustments, along with a mobile team of experts, provided Procter & Gamble with 24/7, real-time facilities management that dramatically reduced energy consumption and costs by 10% within 5 months, and provided a return on investment the first three months.

There are still many barriers to the uptake of smart building technology. In many organisations, the IT and real estate departments work in silos, and smart building solutions fall between the cracks. If property managers are not familiar with the IT component of smart buildings and IT people are not familiar with real estate aspects, then neither department is willing to take ownership. Another challenge is in trying to choose the most appropriate solution amongst the overwhelming range of smart building technologies.

Another barrier is the misperception that smart building solutions are expensive. The truth is that smart building and technology investments typically pay for themselves in 12 to 18 months, thanks to energy savings and other operational efficiencies. In some cases, where these systems identify significant operational issues at the onset, the payback can be immediate.

Conclusion

Whether carbon reduction is driven by legislation such as in Europe or by bottom-up community initiatives such as in America, the deep energy and carbon savings needed to mitigate climate change will require a combination of measures: efficient systems and equipment, occupant engagement and improved operations. Systems and equipment upgrades need to be selected using an integrated energy retrofit approach to benefit from synergies between measures related to lighting, envelope, use of renewable energies and HVAC. The occupants' use of energy is now being recognized as a significant contributing factor to energy performance of a building. This can be addressed through green leases which reward energy conservation. The greatest technology advance, however, relates to building operations in the form of smart building technology, which provides effective and affordable energy monitoring – of the base building as well as in tenancies - and ongoing commissioning. Smart upgrades have made immense impacts on manufacturing, and infrastructure. The time has come to apply smart technology to mainstream real estate. This is the new frontier in our efforts to achieve the energy and emissions reductions needed to stabilize the climate change.

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Zero energy equipment building Lucia: a case study according to European directive

Speakers:
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[1] Universidad de Valladolid, España
[2] Torre de Comares Arquitectos slp. Valladolid, Espanña

Abstract *The University of Valladolid has constructed itself an applied research building for laboratories and spin-off related to research, called LUCIA, which shows that to reach a zero CO2 emissions building with an affordable cost is possible, using combined passive strategies (specially from design decisions), only renewable energies (geothermal, photovoltaic and biomass) and social aspects which can have strong impacts on local development. It offers a model for conducting research into areas that will shed light on other as yet unexplored methods, reducing demand to 81,82 kWh/*m2 *year (totally acclimatized) and yielding a "ZERO CO2" and "CERO ENERGY" building, according Directive 2010/31/ EU. The total cost of the building was 8.225.000 € (VAT included), covering a total built area of 7500 m2 (5920 m2 acclimatized). It has been evaluated, opting to LEED-Platinum and more than four leaves V.E.R.D.E. Funding comes from Junta de Castilla y León and the European Regional Development Fund.*

Keywords, Zero Energy, Zero CO2, Bioclimatic, Equipment, Design

INTRODUCTION

The LUCIA building will be used for laboratories and will provide areas for spin-offs related to nutrition, food, and dietetics; metabolopathies as well as the development of the Digital Knowledge Society. It will offer the chance to investigate a range of features that will shed light on other as yet unexplored areas, using only renewable energies. Strategies lay in the fields of reducing energy demands through bioclimatic design, efficient systems, use of local resources and important training and dissemination activities, which are provided to the user's implication. The integral use of local resources (bio-mass) implies researching in an area with great potential in local job creation.

The Directive 2010/31/ EU of 19 May 2010 urges member states to ensure that all new buildings are "nearly zero energy consumption" through 31 December 2020 (2018 for public administration buildings). The building LUCIA shows a spectacular example both in very low rate of energy consumption, and cero CO2 emission building. According to the E-Quest evaluation system, (DOE-2 program E-Quest 3.64), compared to ASHRAE baseline building, LUCIA shows saving demands of 90% (heating); 41% (refrigeration) and 61% electricity for light. The final energy demand of the buildings is 81,82 kWh/m2 year, the energy balance including HVAC (heating, ventilation, and air conditioning). Annual production of the building is 0 (zero CO2 emissions).

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1. VIVAMUS SODALES SAPIEN SED NISI LOBORTIS, AC RHONCUS SAPIEN PORTA. PRAESENT NON ENIM NON ERAT INTRODUCTION

Those results will be checked; because the building includes a sophisticate integral building management system (BMS) called DESIGO INSIGHT from Siemens, based in SCADA technology (Supervisory Control and Data Acquisition software). Control system operations and data transfer (based in LON / KNX / MODBUS technologies) conduct to analyze the real effect of energy efficiency measures implemented results isolating variations in demand not attributable to own efficiency measures installed.

2. STRATEGIES ABOUT SAVING ENERGY

2-1. Passive and compact bio-climatic design to reduce heating and cooling demand.

The building has a 0.37m-1 form factor for its 5,920 m2 of usable space, giving a ratio which is hard to improve. (Fig. 1) Compactness means the relation between surface and [i]envelope and the climate controlled area can be optimised, thereby reducing the former. Added to that, the specific design of external area, local vegetation, deciduous trees, implementation of green permeable pavement on the park area and the sedum type intensive vegetation (73.5% of the surface on the green roof), produce a microclimate to reduce the heat island effect at the site (VALBUENA, F. GONZÁLEZ, MJ, 2012).

Fig. 1- Optimized compactness- South- West façade.

Fig.2 Zig-zag façade to obtain self-shadowing effect.

2.2. Form façade design:

The characteristics of the site require long walls facing South-West and North-East. This meant that a careful re-orientation study was performed when designing the spaces combined with the eaves in the parts facing the sun. (Figure 2) Using this system, 89% of the surface openings face South and East, achieving thermal gains in winter, and a self-shadowing effect in summer, thereby reducing the cooling load, whilst at the same time ensuring natural light. On its longest sides, the resulting surface resembles a “saw-tooth”, one drawback being the increased surface envelope. This strategy of design leads to a 24% reduction in the building’s cooling loads, according to the simulations carried out.

2.3. Strong Insulation:

The thermal transfer coefficients used in the building envelope compared to those stipulated by Spanish Building Regulations (CTE) and ASHRAE (ASHRAE 2007) are really important: The insulation coefficients used, a key factor (U=0.17 W/m^2K on facades, and U= 0.15

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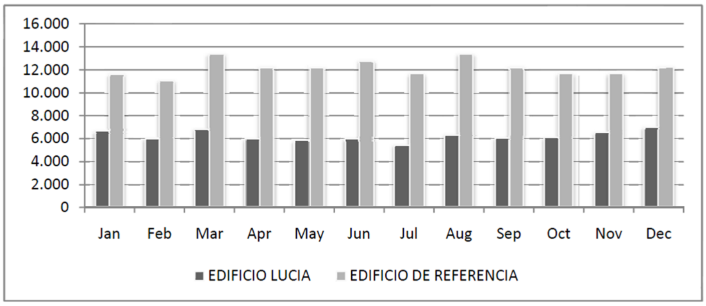
W/m^2K on the green roof) will restrict loss through transfer and therefore lead to a reduction in demand. One drawback is the increased energy in the materials that can be reduced or even removed through the use of natural insulation (100% natural from wood), and an extra financial cost which is offset by the reduction in energy consumption. One further aspect to be taken into account in this section is the effect of thermal inertia achieved in the structure of the building itself (reinforced concrete), particularly with the green roof, which covers 73.5% of its surface.

2.4. Improvement of Natural Lighting using solar tubes:

The decision to construct a compact building has been merged with an increase in natural lighting of indoor areas through the widespread use of tubular day lighting devices or solar-tubes (27 in all) and skylights above the staircases (Fig 3 and 4). In addition to offering beneficial effects for health and wellbeing, natural light reduces the electricity requirement for artificial light: these are static elements which simply reflect incident sunlight, as a result of which they require no power to work. (Table 2).

Fig 3 - Tubular daylighting devices (Solatubes) in green roof

Fig. 4- Internal staircases with skylight



ILUMINACIÓN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
LUCIA (kWh)	6.640	5.990	6.810	5.960	5.800	5.980	5.420	6.330	6.040	6.070	6.480	6.980	**74.490**
REFERENCIA (kWh)	11.650	11.070	13.400	12.230	12.230	12.810	11.650	13.400	12.230	11.650	11.650	12.230	**146.190**

Tabla 2. Save energy with daylight System compared to ASHRAE reference building (DOE-2 from EQUEST 3.64).Dark grey: Lucia building. Pale grey: ASHRAE reference building

2.5. Open design of park places.

In addition to the personal benefits (an open-plan car park is far more pleasant than a closed one), taking such a decision allows for natural ventilation and lighting, allows green

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permeable pavement, and drastically reducing the need for artificial lighting, fire-fighting facilities, anti-CO2 equipment, and so on. (Fig 5)

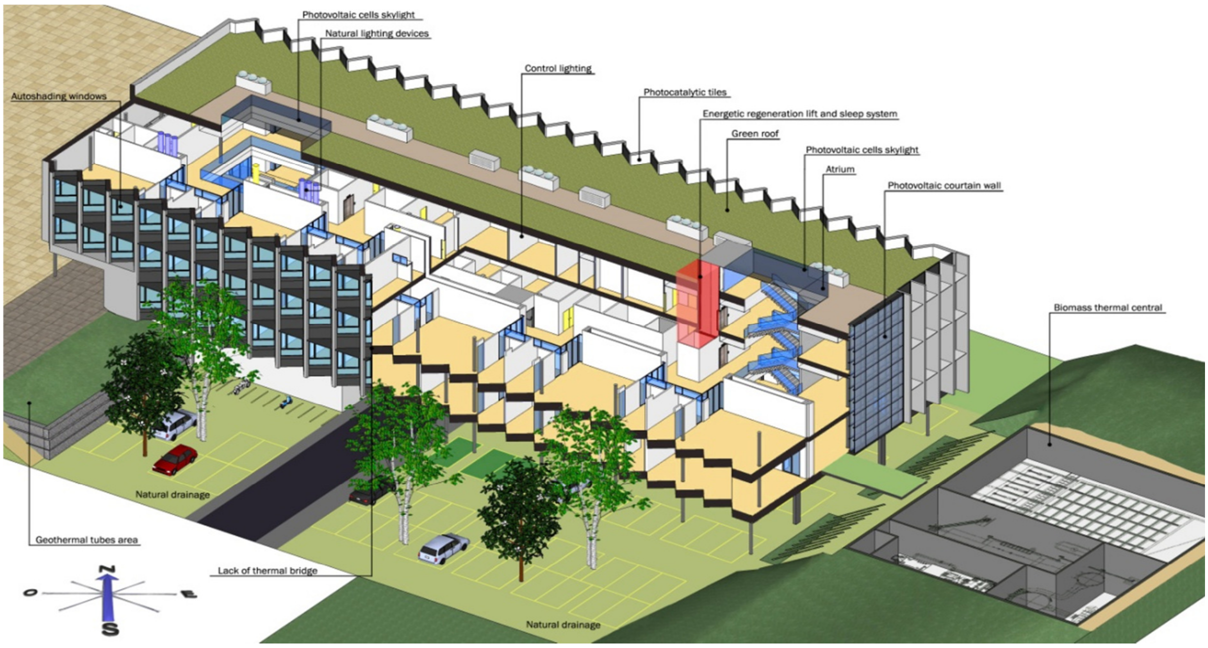

Fig. 5. Axonometric section: Green roof, Tubular day-lighting devices, open car park, and biomass place

2.6. Special control devices

Using energy efficiency equipment (saving energy lifts) and Digital Addressable Lighting Interface (DALI), a communication interface system for lighting to regulate according to natural daylight.

3. USE OF RENEWAB

3.1. Geothermal

The site covers a large environmental conditions ventilation systems using conditions outdoor air na deemed both a bioclimatic Geothermal tubes to produ

Fig 6- Different construction phases of geothermal pipes.

3.2. Photovoltaic

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The architectural design of the building merges photovoltaic systems in two ideal areas: the double skin curtain wall (Fig. 7 and 8) in the South-East facing wall (where common rest areas are located) and two skylights above each of the staircase areas (Fig. 9). The actual photovoltaic panels themselves and the double skin allow this strong natural light to be filtered into the building's interior. The double skin facade produces 5,000 kWh per year and the skylights 5,500 kWh, leading to an annual saving of 3,570.00 euros. They contribute to the building's positive renewable energy balance as well as encouraging research into the topic such that, in addition to producing electrical energy, the skylights aid climate control in the building, both in winter and summer. This entails an added cost in financial terms which is offset by the constant reduction in energy consumption, further research, and emission reduction.

Fig. 7 and 8- Integration in façade of double skin curtain wall (External and internal). Fig 9- skylights above the staircase

3.3. Biomass

Use of biomass, a surplus resource in the region (Castilla y León- Spain) where the building is being constructed, has a major socio-economic impact, and will lead not only to job creation but also to enhanced self-sufficiency in energy. Especially worthy of note among the power generating systems is a cogeneration system that uses lignocellulosic biomass as fuel, and which covers most of the building's thermal (heating, cooling, ventilation, ACS) and electricity demand. The cogeneration system based on biomass, operates as a self-sufficient system from the power point of view. In this sense, the 100 kW of electric power generated by the cogeneration system allows the annual electrical requirements to be covered, and the average value of 180 kW of thermal energy generated satisfy the thermal needs of the absorption chiller responsible for supplying the building with cooling needs. In any case, and given the special characteristics of the building's use (biomedical laboratories), the system is connected to the grid, has a support biomass boiler and a hot water tank that allows the energy supplied to adapt to instantaneous variations in the building's power demand throughout the year. (VALBUENA & HORRILLO 2013) Foundation for small-scale cogeneration based on the gasification of biomass because this new system fits the building's needs, thus achieving an autonomy that can serve as an example for other buildings of the tertiary sector.

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4. OTHER STRATEGIES ABOUT SUSTAINABILITY

4.1. Reduced water consumption has been achieved by; collecting and reusing rainwater (73%) and all grey water (100%), with networks which separate those from the laboratory water to be processed before discharge; bathroom facilities equipped with electronic taps that incorporate flow reduction; the use of autochthonous vegetation that does not require mechanical watering, etc.

4.2. Strong selection of constructions materials: low-environmental impact ; low embodied energy; no-VOC; recycled end renewal; methods which reduce as much as possible the waste generated during the building process (prefabricated, dry wall partition, etc); provide for easy disassembly. Even recycled materials as well as reused building materials are employed, in addition to photocatalytic building materials based in applications of TiO_2.

4.3. A further aspect taken into consideration is waste management during the construction phase as well as during the building's use. The project includes a plan for studying all the waste generated during the building's life-cycle, and the creation of compost from vegetable waste is also envisaged. Finally, the waste generated during future demolition of the building has also been studied with a view to securing the maximum possible recovery of the materials used.

4.4. Improvement of devices and facilities for people with disabilities;

4.5 Educational plan about maintenance for technicians; information to staff, users and personal form the University and general people to improve the general knowledge of environmental items related to buildings. (JANDA K, B. 2011), (WARD et all, 2012)

5 . RESULTS

According to VERDE environmental assessment method (TORRE DE COMARES ARQUITECTOS 2014), the provisional ratios reach by LUCIA building as built is shown in the Fig 10 (last column: reached impact over 5) in different environmental impacts

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Resultados de la evaluación Absoluta									
•	*Los datos estan basados sobre las puntuaciones obtenida en la Auto-evaluacion*	*Indicador/ m2 año*	Peso	Edificio de Referencia	Edificio objeto	Impacto Evitado	% de Redución de Impacto	% de Impacto	Impacto Evitado Reltivo
1	Cambio Climatico	kg CO2eq	27%	90,64	12,67	77,97	90,5%	9,5%	4,5
2	Aumento de las radiacione UV a nivel del suelo	kg CFC11eq	0%	0,00	0,00	0,00	0,0%	100,0%	0,0
3	Perdida de fertilidad	Kg SO2eq	5%	0,0111	0,0002	0,01	98,5%	1,5%	4,9
4	Perdida de vida acuática	kg PO4eq	6%	0,01	0,00	0,01	100,0%	0,0%	5,0
5	Emision de productos foto-oxidantes	kg C2H4eq	8%	0,01	0,00	0,01	99,9%	0,1%	5,0
6	Cambios en la biodiversidad	%	4%	100%	-4%	1,04	100,0%	0,0%	5,0
7	Agotamiento de energía no renovable, energía primaria	MJ	8%	1117,02	689,47	427,55	39,7%	60,3%	2,0
8	Agotamiento de recursos no renovable diferente de la energía primaria	kg de Sb	9%	74,67	58,46	16,21	100,0%	0,0%	5,0
9	Agotamiento de aguas potables	m3	10%	0,34	-0,02	0,36	100,0%	0,0%	5,0
11	Generación de residuos no peligrosos	kg	6%	35,86	1,79	34,07	100,0%	0,0%	5,0
16	Salud, bienestar y productividad para los usuarios	%	12%	100%	12%	0,88	87,7%	12,3%	4,4
19	Riesgo financiero o beneficios para los inversores-Coste del Ciclo de Vida	€ (EUR)	5%	38,96	15,03	23,94	100,0%	0,0%	5,0
	Impacto Evitado		100%						4,55

Fig 10: Impacts of LUCIA building -Provisional VERDE tool (Column 2: 1-Climate change; 2-UV radiations; 3- Infertility; 4- Water habitat destruction; 5- Photo-oxidants emissions; 6- Biodiversity changes; 7- Primary non renewable energy; 8- Other energy no renewable neither primary; 9- Depletion potable water; 11- No hazardous waste generation; 16- Health and wellbeing of users; 19- Economical risk and LCA cost.)

In the field of energy results and its economical maintenance costs, the E-Quest model (VEGA INGENIERÍA 2013) shows the comparison versus baseline building, the building excluded the generation system (LUCIA v/o CHP) and the final building with the generation power system. (Table 3)

ENERGY DEMAND	BASELINE BUILDING		LUCIA W/O CHP		LUCIA BUILDING	
COOLING	54.32	kWh/m2	31.97	kWh/m2	31.97	kWh/m2
HEATING	58.72	kWh/m2	6.02	kWh/m2	6.02	kWh/m2
ELECTRICITY	68.77	kWh/m2	31.33	kWh/m2	38.59	kWh/m2
SANITARY HOT WATER	5.24	kWh/m2	5.24	kWh/m2	5.24	kWh/m2
TOTAL W/O EQUIPMENT	187.05	kWh/m2	74.56	kWh/m2	81.82	kWh/m2
EQUIPMENT (PROCESS)	73.73	kWh/m2	73.73	kWh/m2	73.73	kWh/m2
TOTAL	260.78	kWh/m2	148.29	kWh/m2	155.55	kWh/m2
FINAL ENERGY USE	BASELINE BUILDING		LUCIA W/O CHP		LUCIA BUILDING	
TOTAL W/O EQUIPMENT	196.85	kWh/m2	116.29	kWh/m2	258.25	kWh/m2
PRIMARY ENERGY USE	BASELINE BUILDING		LUCIA W/O CHP		LUCIA BUILDING	
TOTAL W/O EQUIPMENT	339.98	kWh/m2	166.52	kWh/m2	258.25	kWh/m2
CO2 EMISSIONS	BASELINE BUILDING		LUCIA W/O CHP		LUCIA BUILDING	
TOTAL W/O EQUIPMENT	150.84	kg CO2/m2	52.93	kg CO2/m2	0.00	kg CO2/m2
ECONOMIC COST	BASELINE BUILDING		LUCIA W/O CHP		LUCIA BUILDING	
TOTAL W/O EQUIPMENT	16.68	€ / m2	6.64	€ / m2	4.30	€ / m2

Table 3- final results about energy and co2 of LUCIA building according E-QUEST

6. CONCLUSIONS

The building proves that achieving energy independence is possible, and shows how to improve the use of surplus material in the region, such as forest wood, which can also lead to the creation of new jobs. The building will be "zero emission", and will provide the springboard for research into social aspects of building sustainability. It will constitute a prototype on which to test hypotheses that will provide the bases for environmental methods and assessment for buildings. It could be an example for NZEB ratios, specially the demand reached of 81,82 kWh per m2 year for tertiary sector buildings. The maintenance cost of 4.30 €/m2 (including no equipment) is highly reduced compared to a baseline building. We believe that the systems and strategies used can be replicated when constructing tertiary-sector buildings aiming to be energetically self-sufficient, and also for NZEB. The bio-climate design and passive strategies are replicable in any type of building, even in those subject to rehabilitation. Something similar occurs with integrated photovoltaic systems or Geothermics. The results of this example will be spread to other new University buildings and the use of bio-energy in central-heating systems in existing ones in the Campus. More information: http://lucia-building.blogspot.com.es/ Funding comes from Junta de Castilla y León (Program of Infrastructure of Research and Technological Development), and the European Regional Development Fund.

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The path to zero carbon - let's have all the options

Speakers:

Woolcock, J [1]

[1] Sustainability House, Adelaide, Australia

Abstract: Building energy rating schemes are set up to achieve an outcome such as greenhouse gas reduction. Some schemes estimate operational energy using rating tools. A rating tool provides the user with one possible outcome each time the software is run. Economies of scale push volume builders to use the same specification in each building.

In Australia the scheme is intended to reduce greenhouse gas emissions through improvements to the thermal performance of the building shell. The assessment is done at the design stage. Construction cost is most often the primary driver for building development, with little consideration given to the operational costs or embodied energy. The builder is dependent on a passing assessment for construction approval, but as they don't pay operational energy costs there is little incentive to explore specification and design options.

Using cloud computing, millions of thermal performance assessments can be completed. With the addition of construction costs, operational costs and embodied energy it is possible to show a path to cost-effective zero carbon buildings.

Keywords - simulation, thermal performance, cost, embodied energy, zero carbon, cloud computing

The Problem

Energy efficient buildings provide a benefit to their occupants in reduced energy bills and better health. Factors which impede the construction of more energy efficient buildings in Australia, include; perceived increase in construction costs, lack of offering from builders, lack of request from purchasers.

Australian residential buildings are, on average, the largest in the world. In the major urban centres the construction of single detached dwellings is still at 50%, elsewhere in the country 75% of the residential buildings are detached houses.

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To obtain a construction permit, documentation must be provided to demonstrate the building complies with the Building Code of Australia (BCA). The BCA sets minimum performance standards for structure, fire, amenity and energy efficiency.

One way a building can comply with the energy efficiency regulation is to use simulation to estimate the expected performance of the building. Three software simulation tools have accreditation, they use the same calculation engine, developed by the government science agency CSIRO. The calculation engine only assesses heating and cooling loads. The tool creates a 'star rating' from the simulation result using an occupancy pattern, a set of comfort temperatures and a set of starbands. The starbands vary with location and climate.

The BCA sets the minimum acceptable energy efficiency standard at 6 out of 10 stars. A 10 star house should maintain a comfortable temperature range of 20 to 25 degC in daytime living areas without any external heating or cooling. The starband scales are logarithmic. A 6 star house might sound good when compared with other star rating schemes, such as that for hotels, but a 6 star house is not a high performance building.

A recent monitoring study carried out by the CSIRO[1] showed that the scheme had been effective at restricting heating costs but had done little to curb cooling costs. Scheme criticisms include;

- The assessment is the potential of the building to be used in an energy efficiency efficient manner. It relies on the occupant to act in their own best interest.
- The scheme provides a minimum performance benchmark, but no incentive to build high performance buildings.
- The rating tool has a 24 hr occupancy pattern, someone is at home all day every day, leading to a solution favouring buildings with thermal mass.

Regulatory assessments are carried out by Thermal Performance Assessors (TPA). Generally TPAs work from architectural drawings and specifications. They provide a report which is part of the documentation submitted to the certifying authority who grants building approval.

Most residential buildings constructed in Australia are erected by high volume home builders, companies constructing between 100 and 2,500 dwellings per year.. The market is highly

[1] Ambrose et al (2014), The Evaluation of the 5-Star Energy Efficiency Standard for Residential Buildings http://www.industry.gov.au/Energy/Pages/Evaluation5StarEEfficiencyStandardResidentialBuildings.aspx

competitive and the volume builder use economies of scale to compete on price. The companies provide their clients with;

- a selection of house designs
- selections of materials and finishes
- documentation and building approval
- site supervision, the building work being carried out by sub-contractors

TPA recommended building improvement changes to meet the energy efficiency regulation are sometimes met with resistance. The occupant rather than the builder pays the energy and water bills so there is no direct incentive for the builder to deliver an energy efficient building.

The energy efficiency assessment process is often seen as counter-intuitive. Conventional ideas held by the building industry and the public are not always reflected in the results of the simulation. Generally people design for summer cooling loads though most Australians live in areas which have a predominant winter heating load.

Homeownership represents a strong cultural desire supported by financial incentives, including cash handouts and tax breaks. Housing affordability receives a lots of media time and is seen to be an national economic driver.

Homeowners expect the services, such as electrical and plumbing, to function without their having knowledge or expertise and expect the same for energy efficiency. Experience has shown homebuyers are more willing to spend on luxury items such as granite benchtops rather than to invest in their thermal comfort and saving from reduced operational energy bills.

Complexity

Building thermal performance is complex. The performance outcome when compared to changes in variables is not linear and even experienced TPAs are unable to predict the outcome of an assessment based on visual inspection.

Where buildings do not meet the minimum standard the TPA becomes the building designer, offering solutions to get the building to reach the regulatory minimum. Having no accurate idea of the building costs, the TPA generally stops when they reach the regulatory minimum. This may not be the best solution.

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Why can't we have all the answers?
Currently the problem is too many variables and not enough TPA time to find the optimal result. A solution is to automate the assessment in order to allow for all variable combinations to be tested.

The Process

The TPA assesses the building using the simulation software and submits the assessment along with a set of parameters to be tested. The software application, RoboRater, uses cloud computing to simulate all combinations. It can take a TPA two minutes to make a single change to the building. RoboRater can perform more than 10,000 changes per minute.

Construction Costs & Carbon Figures

The simulation assessment file contains the building's dimensions and material specification.

This information can be used to estimate the cost of the building and its embodied energy.

Example
Boundaries: The following are included;

- Construction materials - embodied emissions for their manufacture
- Operational energy - energy used to heat and cool the home

The following are excluded;

- Construction materials - Transport, End-of-life
- Operational energy - Energy used outside heating and cooling, eg lighting and appliances

Costs: For the purpose of this study costs have been supplied by a quantity surveyor. Figures for the embodied energy of the building materials draws on existing carbon inventories such as Eco-invent and the Australian database supplied with the Simapro software v7.3.3.
Climate: Adelaide, Australia - a temperate climate with hot, dry summers and cool, wet winters.

Building: The example building is a standard plan from a volume home builder. It has a 190m2 floor area and window to floor area ratio of 18% . Plans for the building are in Figure 1.

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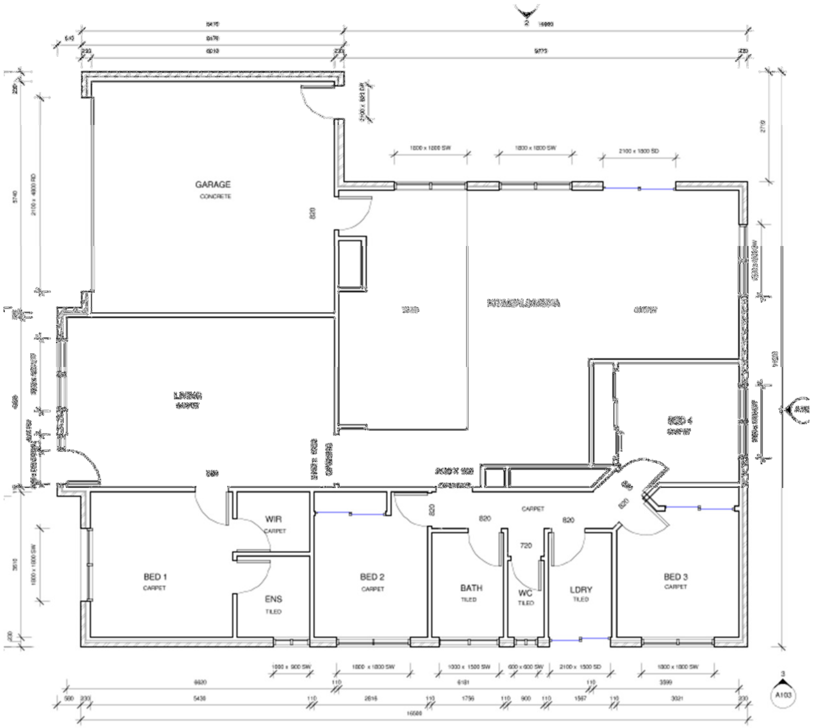

Figure 1 - Example house plan

The constructions tested in the study are detailed in Table 1.
89,856 individual building specifications were assessed.

Table 1 - Building specification options tested

Building orientations (2 options) Front door south Front door west	
Walls (13 options) Brick Veneer + R2.5 bulk ins - (BVR25) Brick Veneer + R2 bulk ins - (BVR2) BV + R2 bulk ins + 1 refl -airgap - (BVR25RF) Brick Veneer + R1.5 bulk ins - (BVR15) BV + R1.5 bulk ins + 1 refl air-gap (BVR15RF) Cavity brick - (CB) Cavity brick + 8mm polyurathane foam + 2 reflective air-gaps - (CB8mm)	Fibre Cement Sheet + R2.5 bulk ins - (FCR25) Fibre Cement Sheet + R2 bulk ins - (FCR2) FC + R2 bulk in + 1 reflective air-gap - (FCR2RF) Fibre Cement Sheet + R1.5 bulk in - (FCR15) FC + R1.5 bulk ins + 1 refl air-gaps - (FCR15RF)

Cavity brick + 2 reflective air-gaps - (CBRF)	
Roof colour (3 options) Light (30% solar absorptance) Medium (50% solar absorptance) Dark (85% solar absorptance)	Ventilation of the roof space (2 options) Vented Not Vented
Removable window shading (2 options) Shading on Shading off	Reflective roof space (2 options) No reflective air-gaps Two reflective air-gaps
Eaves (3 options) No eaves 450 mm eaves 750 mm eaves	Ceiling fans (2 options) Present in living and bedroom zones Absent
Ceiling insulation - bulk (4 options) R2.5 R3.5 R4.0 R5.0	Windows (6 options) Al frame 4mm single clear glass (hiUhiSHGC) Al frame 4mm single tinted glass (hiUloSHGC) Imp Al frame 6mm low-e glass (meUhiSHGC) Timber frame 4mm clear glass (meUloSHGC) Timber double glazed tinted glass (loUhiSHGC) Timber double glazed clear low-e glass (loUloSHGC)

Results

Construction Cost v Star Rating

The costs for the house varied from $249,995 to $296,000. The specification for those are seen in Table 2. Figure 2 shows the building cost compared to star rating.

Table 2 - Building specifications, highest cost, lowest cost

Orient	Ext	Roof	Roof	Roof	Wind	Eave	Window	Ceiling	Ceiling	Star	Cost

	wall	vent	colour	Refl	shade			fan	ins		
FDS	CB8mm	Y	Light	N	Y	750	loUhiSHGC	y	R5	8.2	276,720
FDS	BVR15	Y	Light	Y	N	0	hiUhiSHGC	n	R2.5	5.4	229,995

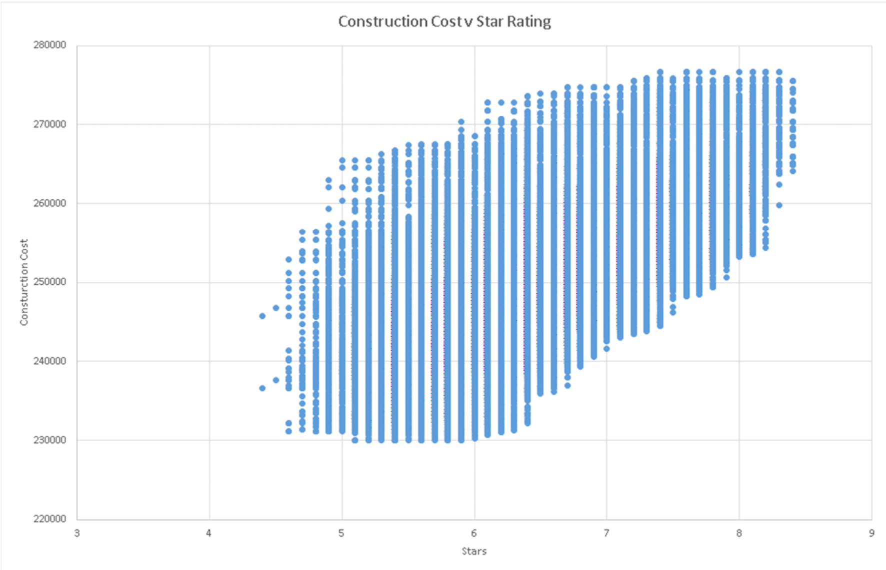

Figure 2 - Construction cost v star rating for a range of construction options[2]

Construction embodied energy v Star rating

Figure 3 shows the graph of embodied energy v star rating. The split into three groups reflects the differences in the construction of the external walls. Embodied energy is not currently considered in construction in Australia so there is no correlation between star rating and embodied energy.

[2] Explanation of figures; each figure shows a factor plotted against the star rating. Each line in the histogram is is made up of dots, each dot is a building specification. The simulation software gives star rating results as 0.1 stars, which is why the data is in bands.

2

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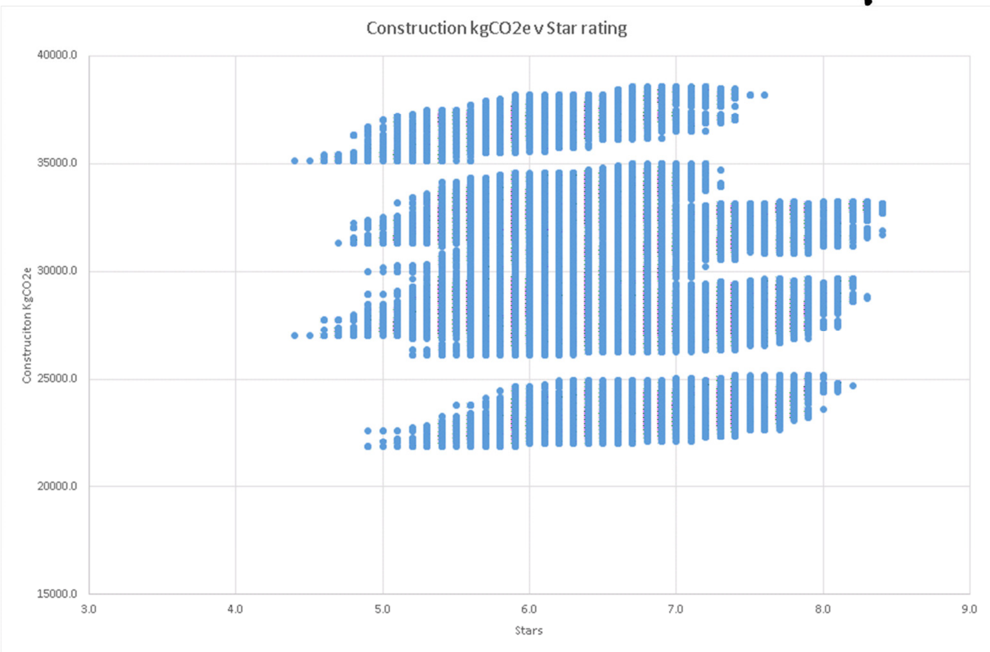

Figure 3 - Construction CO2e V Star rating

Lifetime Cost v Star Rating

Typical building lifetime in Australia for the type used in the example is 40 years. The total lifetime cost of the building was estimated by adding the construction cost to the operational heating and cooling cost. The heating and cooling cost was derived from the heating and cooling loads calculated by the simulation software, applying an expected heating and cooling Coefficient of Performance of 3.1, and a cost of electricity per kwh of $0.32. The highest and lowest costs can be seen in Table 6. The figures show there is substantial saving over the lifetime of the building. The data for 40 year lifetime cost can be seen in Figure 4.

Table 6 - Highest and lowest total cost for 40 year lifetime.

Orient	Ext wall	Roof vent	Roof colour	Roof Refl	Wind shade	Eave	Window	Ceilin g fan	Ceiling ins	Star	Cost
FDS	CB	N	Dark	N	N	0	hiUloSHGC	N	R2.5	4.4	489175
FDW	CB8mm	N	Light	Y	Y	0	loUhiSHGC	Y	R5	8.4	322818

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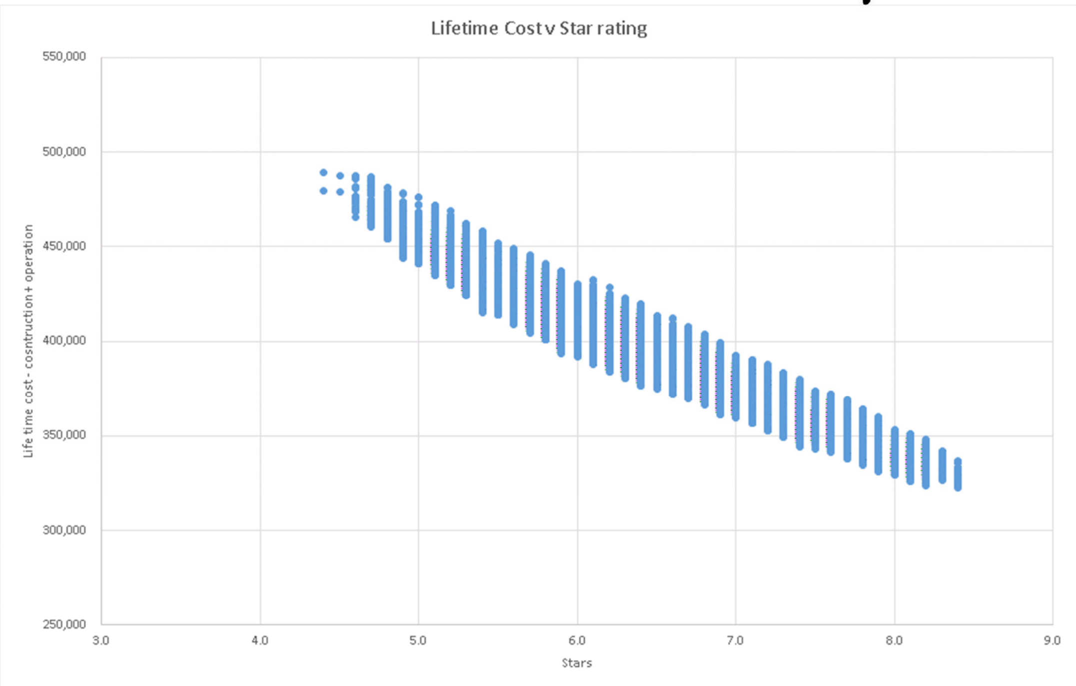

Figure 4 - Lifetime construction + heating/cooling cost v Star rating

Zero Carbon

The lowest total emission building can be seen in Table 7.

Table 7 - Lowest kgCO2e building specification

Orient	Ext wall	Roof vent	Roof colour	Roof Refl	Wind shade	Eave	Window	Ceiling fan	Ceiling ins	Star	kgCO2e
FDW	FCR2RF	Y	Light	N	Y	0	loUhiSHGC	Y	R3.5	7.7	27925

The roof of the building has approximately 50 m2 of roof area facing North. Assuming ideal conditions, this would enable the installation of a 5 kw photovoltaic array offsetting approximately 5,000 kgCO2/year. Allowing two years for the system to generate enough power to offset its own embodied energy, the building could be carbon positive for its construction and heating and cooling energy in as little as 8 years.

Conclusion

Generally buildings are designed and specified in a business-as-usual way with minor changes being made at the end of the design process to meet regulatory minimums.

The power of cloud computing to simulate all possible options at the design and specification stage can lead to substantial savings in both construction cost and energy bills. This study demonstrates the savings can be large enough to enable the offset of both the embodied and operational energy leading to a cost effective zero carbon building

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Session 119:

What issues are going to define the Windows of tomorrow?

Chairperson:

Zamora, Joan Lluís

Professor Universitat Politècnica de Catalunya

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Energy rating of windows for the cooling season: a proposal for Europe (Best Papers SB13 Portugal)

Speakers:
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Abstract: *The proposed paper attempts to propose a new system for assessing the cooling performance of the windows at a pan-European level. Within this context, climatic zones were defined. A detailed analysis of the energy performance of the windows on every proposed climatic zone of Europe followed, conducted as the dynamic simulation of the energy needs of a reference unit with different window alternatives (geometry, thermal and the optical characteristics of the window, orientation and use of the reference room used for the analysis). Based on the results, a rating system for the cooling energy performance of windows was developed, which can be used with regard to their thermal and optical characteristics for different orientations and climate zones of Europe.*

Rating, energy performance, cooling, window energy index

Introduction

Fenestration has always been regarded as the weakest component of the building envelope, due to its higher thermal and solar transmittance, which is reasponsible for high thermal losses in winter and solar heat gains in summer. Therefore, heat transfer through windows accounts for a significant proportion of all energy used in the building sector. However, although considerable advances have been made in the window technology in recent times in order to confront such weaknesses, it is not always easy to select the optimal product due to the plethora of choices and the conflicting functions of the building element. The energy rating and labeling of windows delivers the simple, straightforward information that is needed for making energy efficient decisions, facilitating thus the enhancement of the building energy performance.

Due to the free movement of goods in the EU, the idea for developing an energy rating and labeling scheme for windows that could be used all over Europe seems reasonable; the scheme will have to propose the energy parameters and the calculation methodology, upon which the rating will be based. The applicability of the rating scheme in every European region can be assured by the establishment of climate zones in the European region with regard to the climatic characteristics, as well as by including both heating and cooling energy needs in the calculations. Furthermore, the distinction between residential and office use is also essential, mostly due to the deviations between the air quality requirements and the ventilation patterns, as well as the internal heat loads and generally the usage profile.

In the present paper, the development of a rating scheme for assessing the cooling energy performance of windows in Europe is attempted. The calculation methodology presented in the next sections includes the establishment of the climate zones used for the study, the definition of the energy parameters that were regarded as the basis of the analysis as well as the description of the parametric analysis, which led to the development of the mathematical formulas for the estimation of window cooling energy performance. The proposed rating scheme is introduced synoptically.

The methodological approach

The degree-day approach was considered as the most appropriate method for characterizing the climate severity, since it can be used for a quick estimation of the heating or cooling energy consumption of a building, especially when the utilization of the building and the efficiency of the heating equipment can be assumed constant [1]. The term heating (or cooling) degree days is defined as the positive deviation of the mean daily temperature T_m from a base temperature T_b, practically the outdoor ambient temperature, above which heating (or cooling) is activated to sustain the indoor temperature to a comfortable level. The basic temperature depends on the constructional specifications of buildings and their application in research. For heating, the traditional degree-day or degree-hour procedure is based on a combination of theory and empirical observations and assumes that, on a long-term average, solar and internal gains will offset heat loss when the mean daily outdoor temperature is 18.3°C and that energy consumption will be proportional to the difference between the mean daily temperature and 18.3°C [2].

Within the context of this objective, the cooling and heating degree days of selected cities across Europe were calculated at a base temperature of 18°C. The cities were selected on the basis of their population and availability of climate data. More specifically, all cities with a population over 100000 inhabitants were taken into account and among them, only 121 fulfilled the criterion of climate data availability. Based on the climatic conditions prevailing on the selected European cities, a categorization into zones was proposed according to the region's heating and cooling needs, which are depicted by the number of Heating Degree Days and Cooling Degree Days. The value of 500 CDD was regarded as the threshold, above which the climate can be characterized as cooling dominated; the value of 2500 HDD (also found in literature) was regarded as the border for heating dominating climates [3]. Lower values of HDD and CDD indicate lower energy needs for heating and cooling respectively. The cities with a cooling dominating climate (Zone A) are located at the southern part of Europe and along the coastal regions of the Mediterranean. Zone B embraces the continental areas of Italy and Spain as well as the coastal areas of northern France and Spain. The remaining cities comprise zone C and are characterized by their wintry weather.

The cooling energy performance was assessed through the calculation of the cooling energy index, q_c, which represents the energy contribution of the rated window. It is calculated as the difference between the annual needs for covering the cooling requirements of the reference room with the examined window system, Q_c,, and the annual needs for cooling requirements of a notional room, Q_{c,no_win}, which is identical to the reference one, but its window is adiabatic (U=0) and non transparent to solar radiation (g=0), divided by the window surface, A_w [4-6]:

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$$q_c = \frac{Q_c - Q_{c,no\_win}}{A_w}$$

The cooling energy needs of the reference unit, Q_c and Q_{c,no_win}, were calculated with the help of Energy+, an energy analysis and thermal load simulation program, which enabled the detailed dynamic analysis in every case. Energy needs are preferred to energy consumption, since there are various HVAC systems, which actually differ enormously from country to country. The philosophy of this methodology is in accordance with ISO 18292 [6].

The cooling needs derived for each examined window were calculated for a reference room, the geometry of which is defined in international standards. It is of rectangular plan, 3.6m wide and 5.5m long, with a storey height of 2.8m. This configuration was selected as it was assumed that both an office and a residential building could be formed by the multiplication of the reference unit. For the analysis, all opaque building components of the reference room were regarded as adiabatic, with the exception of the front wall, which was regarded as thermally insulated with a 0.05m layer of EPS (λ=0.04 W/(m K)) positioned on its external surface. The window is located on the front wall and covers an area that varies from 10% to 99% of the façade.

Two usage profiles were taken into account; as regards office, it was assumed that it is occupied during the working days of the week (Monday to Friday) from 07:00 till 17:00 all year long. Only during this operating time the HVAC systems are in operation. The cooling and the heating set-points were considered equal to 24.5°C and 22°C, in accordance with EN 15251 [7]. Internal loads were regarded equal to 132Wh per day, which account for 13.76W/m² during the operating time and 2 W/m² for the remaining time. Ventilation varied from 0.8ACH to 1.50ACH for Mediterranean countries, while for the rest of the Europe it was considered equal to 0.50ACH. In order to take into account the increased air permeability commonly found in the Mediterranean structures, infiltration was considered equal to 0.50ACH for the specific zone and 0.2ACH for the rest of Europe. For the residential usage, a full occupational status was taken into account. The cooling set point was considered equal to 26°C in accordance with EN 15251[7]. However, it was assumed that the user would open the window when the indoor air temperature exceeded 24°C with the condition that the ambient air temperature is lower than the one in the interior. In that case, ventilation was regarded equal to 2ACH. With closed windows a ventilation rate of 0.7ACH is required for air quality requirements. Infiltration rate was considered equal to 0.50ACH for the Mediterranean regions and 0.2ACH for the rest of Europe, in order to take into account the increased air permeability of the conventional structures found in the Mediterranean region. The internal thermal loads were considered equal to 5W/m².

For both cases (office and residential usage) alternative scenarios were studied, which differentiated mainly on the fenestration properties and the facades characteristics. As regards the fenestration properties, window products with different thermal and optical properties with respect to their frame fraction were studied. The selected values for the thermal

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transmittance of the window U cover a wide range of conventional and advanced fenestration systems; they range from 0.72W/m²K (passive window) to 3.20W/m²K. Both high (e.g. 0.76) and low (e.g. 0.30) values of the solar transmittance of the glazing ggl were taken into account for each window (apart from the passive window). The solar transmittance of the whole window depends on the area of the transparent element; therefore the changes in frame fraction from 10% to 30% resulted in different values of g. As regards the façade's characteristics, different window sizes and orientations were studied. It was assumed that the window was positioned on the main façade of the room and covered 10%, 25%, 50%, 75%, 90% and 99% of the façade. It was also assumed that the window faced the cardinal orientations, i.e. they were orientated due South, North, East and West.

The parametric analysis described above was conducted for 15 selected cities, which were representative of the climatic zones defined previously. For the coldest zone, the climate files of Aberdeen, Berlin, Stockholm, Tampere and Warsaw were included in the analysis. The continental Europe was represented by Belgrade, Bilbao, Brussels, Madrid and Milan, while zone A encompassed Athens, Larnaca, Lisboa, Malaga and Rome. The climatic data were retrieved from the extensive database of meteorological information of Energy+. For most of the cities the IWEC (International Weather for Energy Calculations) database was used.

It is worth mentioning that for the office occupancy the results of 20160 simulations were used in the analysis, which accounts for 6720 cases for each climatic zone and 1344 for each examined city. For the residential use, the above mentioned numbers are reduced to half, as ventilation was not regarded as an independent parameter in the analysis. Totally 30240 simulations were run for the parametric analysis, resulting to a reliable and consistent sample for the statistical analysis.

Assessment of the cooling performance of the windows

The extensive parametric analysis offered a plethora of significant results, which mainly focused on the contribution of the window's characteristics on the energy balance of the reference unit. This contribution was found to differentiate substantially among the climate zones, the usage profile, the orientation and the window properties.

More specifically it was found that the cooling index reaches much higher levels for the Mediterranean countries, while for the continental Europe the respective values are reduced by at least one half or even one third. For the Northern European cities, the analysis showed that they cooling loads are very limited, resulting to very low or even negative values of cooling energy index, q_c.

Concerning the usage profile, it was found that the cooling energy index of the windows is more substantial when the ventilation is controlled, i.e. in office buildings. For the residential buildings, the free ventilation pattern facilitates the dissipation of warm air towards the ambient environment; in these cases, the windows play a less important, but still significant, role in the formation of cooling loads. In fact, in such cases the solar transmittance of the windows is of greater importance, while for the office mode the role of the thermal transmittance acquires some magnitude. For both uses, the general impression is that the cooling energy index of the windows acquires lower values when the U- value of the window is increased and the g-value of the window is reduced. This practically means that the window is responsible for the increase of cooling loads when its U-value is low, since it prevents the heat flow towards the ambient environment when its air temperature is lower. On the contrary, a low g-value will lead to less solar heat gains through the window, leading to a better cooling performance for the window. Among the two major properties of the window, the solar transmittance seems to be the key for optimizing the cooling energy efficiency. This conclusion is less evident for windows with a North orientation, due to the lower solar radiation incident on Northern façades. The analysis and the justification of all derived conclusions on the cooling energy performance of windows have been presented in previous publication of the authors [4-5].

Development of the rating scheme for the cooling energy performance of windows

The extensive simulation results offered the prospect of employing the statistical analysis for developing formulas that will express the cooling energy performance of windows. Within this context, statistical analysis was conducted with the help of R software. From the results it is derived that among all the parameters that affect cooling energy performance of windows the occupancy status, the climatic characteristics, the orientation, as well as the thermophysical and optical properties of the window play the most important role.

Since there is a strong correlation between the dependent and the aforementioned independent parameters, it was attempted to develop a simplified formula for each occupancy, climatic zone and orientation. The formulas are derived with the help of regression techniques. Regression was conducted to the mean values of q_c calculated for each of the window types. The independent parameters that are taken into account in the analysis are the thermal transmittance U_w and the solar transmittance g_w of the window. Analysis showed that in all cases the most appropriate model is of the form $q_c = b \times U_w + c \times g_w$, where q_c is the cooling energy index of the examined window; U_w is the thermal transmittance of the window; g_w is the solar transmittance of the window; b and c are the coefficients derived from the statistical analysis and are given in Table 1 together with the values of adjusted R.

The proposed rating scheme for the cooling energy performance of windows

In order to propose a rating scheme, a basis for the comparison of the cooling performance should be formed. Given that the examined fenestration types are regarded as representative to the one met in the European constructions, it is logical to categorize their performance with regard to the best (lowest q_c) and the worst (maximum q_c) behavior. Within this context, the minimum and maximum values of q_c of the 28 window types were retrieved and their difference was calculated ($d=q_{c,max}-q_{c,min}$). The calculated value d was divided to three, in order to create 4 categories; the borders between the rating categories were set by adding d/3, 2d/3 and d to the qc,min. The derived limit values between the rating categories are presented in Table 2. Following this approach, more categories could have been formed. The proposed scheme can be used for the assessment of the cooling energy performance of a window by

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applying the coefficient values presented in Table 2, taken into account the properties of the examined window and the climate zone that it is going to be installed. The resulting value will be used for labeling the examined window via the limits of Table 2.

Conclusions

In this paper a proposal for rating the cooling energy performance of windows in Europe is presented. It involves the simplified formulas for the calculation of the cooling energy index, which serves as the critical energy rating parameter for windows, as well as the establishment of the cooling energy categories for the rating scheme. The detailed analysis showed that the rating should be based on the thermal and solar transmittance of the windows, since these parameters appear to have the most significant impact on the formation of cooling energy loads. Additionally, it was regarded necessary to determine the window performance not only with regard to the climate, but also with regard to the orientation of the window and the building use. The merit of the current paper is that it provides an approach for rating the energy performance of windows at a European level, not only by assessing their contribution on the formation of heating loads, but also by taking into account their involvement into the cooling needs. By combining these two components of window energy performance, the selection of energy-efficient windows will be promoted, given the fact that for a significant part of Europe cooling has an equally important role in the building's energy balance.

Table 1. The coefficients b and c used in equation 3 for every use, climate zone and orientation.

Use	Zone	Orientation	b	c	Radj.
Office	Mediterranean	South	-27.6	567	0.995
		East	-18.1	537	0.998
		West	-17.1	481	0.997
		North	-10.4	191	0.998
	Continental	South	-28.0	376	0.989
		East	-21.7	334	0.995
		West	-21.9	325	0.993
		North	-15.1	132	0.984
	Northern European	South	-21.5	243	0.980
		East	-17.0	187	0.983
		West	-16.9	183	0.979
		North	-9.5	64	0.915
Residential	Mediterranean	South	-8.6	333	0.974
		East	-7.9	390	0.994
		West	-6.1	362	0.995
		North	-2.1	118	0.993
	Continental	South	-6.3	159	0.960
		East	-6.3	173	0.988
		West	-5.8	170	0.987
		North	-1.7	47	0.988
	Northern European	South	-3.9	65	0.928
		East	-3.1	50	0.955
		West	-3.1	50	0.964
		North	-0.5	7	0.950

Table 2. The limits of the rating categories of the windows for assessing their cooling energy performance.

Use	Zone	Rank	Orientation			
			South	North	West	East
Office	Mediterranean	D	>245	>79	>252	>254
		C	174-245	55-79	183-252	188-254
		B	102-174	31-55	115-183	121-188

		A	<102	<31	<115	<121
	Continental	D	>136	>33	>129	>129
		C	87-136	16-33	85-129	87-129
		B	38-87	(-2)-16	42-85	44-87
		A	<38	<(-2)	<42	<44
	Northern European	D	>78	>12	>58	>58
		C	46-78	3-12	34-58	34-58
		B	14-46	(-7)-3	9-34	10-34
		A	<14	<(-7)	<9	<10
Residential	Mediterranean	D	>167	>64	>206	>206
		C	125-167	49-64	156-206	157-206
		B	84-125	33-49	106-156	107-157
		A	<84	<33	<106	<107
	Continental	D	>72	>22	>81	>81
		C	53-72	16-22	59-81	59-81
		B	33-53	10-16	38-59%	38-59
		A	<33	<10	<38	<38
	Northern European	D	>28	>39	>29	>28
		C	18-26	30-39	21-29	20-28
		B	9-18	21-30	12-21	12-20
		A	<9	<21	<12	<12

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Timber framed windows in a historical perspective: Energy and cost assessment over the life cycle

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Abstract:
Based on condition data from 2899 Norwegian dwellings assessed 2006-2009, the expected service life of windows was estimated to be 38 years, in accordance with commonly used estimates.

Using a Norwegian building from 1960 as starting point, the consequences (primary energy use and costs) of selected values for window service life was calculated through a 60 Year period, using assumptions of technical performance of replacement windows from years 1980, 2000 and 2010. It is shown that in the climate of Oslo, the lifetime energy consumption and non-renewable energy consumption would be lower with a service life of 10 years than 20, 30 of 60 years.

Lifetime costs would however be lower with a service life of 60 years, assuming a constant ratio of heating cost to window cost. The energy costs are still sufficiently high to defend a much higher initial investment in higher energy performance.

Key words: Life time, window, life cycle costing, life cycle assessment

Introduction

In order to assess the life cycle impact of a product, its expected life time is of importance. Generally, a long expected service life is a virtue, as the economical and environmental investment is discounted over a longer time. However, technological developments that improve performance may reduce the in-use impact of the product to an extent where it would be beneficial to exchange the original product before the end of its technical life.

The case of timber framed windows is interesting to study from this perspective as:

- The heat lost through windows has significant consequences for economy and environment
- The thermal performance of windows has improved over time
- Windows still intact after more than one hundred years use can be found [1], but the effect of technological development on life expectancy has been questioned.

The technical life time of a timber framed window depends on properties of the product itself, such as design, quality of wood, craftsmanship, surface treatment, etc. as well as the conditions for use including climate and maintenance. The actual service life time can often be shorter than technical life time if the windows are changed e.g.due to estetichal issues,

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demands for improved or different functionality or externalities like demolition of the building itself.

The access to a relatively large sample of Norwegian dwellings sold between 2006 and 2009 enabled us to discuss the effect of life time expectancy and technological development on the economical and environmental impact of these windows.

Method

In the period 2006-2009, the technical condition of all dwellings sold through a major Norwegian real estate agent were assessed in a standardized way by an independent company (Anticimex AS). Of these 4677 assessed dwellings, 2899 had complete data on building year and window replacement. The proportion of dwellings with windows still intact at the time of assessment was calculated. In general, the windows were assessed and treated as a single element in the database. If the age or condition differed between windows within the same dwelling, separate "window elements" were created for the dwelling to accodomodate the different data. Thus, we were able to score each building as having original, partly changed or changed windows, as well as score an age for each "window element". However, it was not possible to identify the number of windows within each element, and there was no record of whether the windows had been replaced more than once.

The consequences for energy demand were calculated by dynamic (hourly) simulating the energy demand of a model building with equal number of windows facing S, W, N and E, following the rules in NS 3031 using the software TEK-sjekk ver.13.07.01 [2], with climatic data from Oslo.

Common assumptions for the model building are given in Table 1. As a calulation reference theoretical "ideal" windows with U=0.1 W/m² and no air leakage were used.

Table 1: Input values used for simulations related to energy demand in use phase

	Floor	**Roof**	**Wall**	**Window (opaque)**
U-value (W/m^2)	0,147	0,13	0,5	See table 2
Area (m^2)	100	100	110,7	9,3

Air leakage (n_{50})	**Ventilation rate (1/h)**	**Thermal bridges (W/m^{2}K)**	**Internal loads**
5	0,5 + infiltration	0,05/m^2 Floor area	According to NS 3031

As the consequences for energy demand of air leakages depends on the ventilation system, both balanced heat-recovery ventilation and exhaust ventilation were simulated.

Assumptions on the technical performance of windows were bases on building code requirements, different editions of "Trehusboka" -Wooden House Handbook [3-13], information in SINTEF Byggforsk Design Guidelines and EPDs for relevant products. Assumptions of air leakages were built on [14] demands for window labelling and laboratory values [15]. 1960 was selected as a starting point for the analysis, and scenarios of 10, 20, 30 and 60 years of service life for windows were analysed using assumptions described in Table

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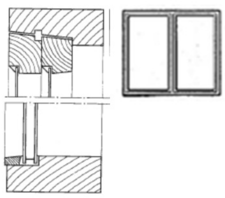
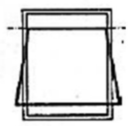
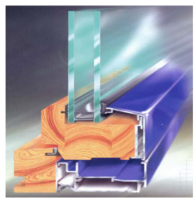
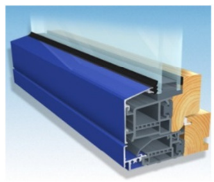
2. All windows are scaled 1.23 x 1.48 m (reference window based on standard EN 14351-1) to be comparable.

Life Cycle Assessment [16], specifically the method of Cumulated Energy Demand [17], was used to calculate embodied non-renewable primary energy demand in a life cycle perspective (end-of-life excluded). Ecoinvent v 2.2 [18] wa used as background database to be able to account the embodied primary energy related to the production chain for each material input. The primary energy factor used for electricity was the mean Norwegian supply mix for the years 2009-2011, and electrical heating was assumed.

Table 2: Description of the different windows related to the years 1960, 1980, 2000 and 2010.

Year	**1960**		**1980**		**2000**		**2010**	
Description	Two-layer, outwards opening, framed with timber		Two-layer, sliding hinged, framed with timber		Two-layer, fixed, framed with wood- and aluminium		Two-layer, sliding hinged, framed with wood and aluminium/plastic	
Illustration					 Figure: H-vinduet Magnor as		 Figure: H-vinduet Magnor as	
U-value [W/m²K]	2,4		2,4		1,6		1,2	
Air tightness, $\dot{V}_{50}$ [m³/h]	47 (20*)		18		18		2,4	
Source, material input	Wigen, 1963		Dreier, 1995		H-vinduet, 2004		H-vinduet 2013	
Unit	**Share [%]**	**Mass [kg]**	**Share [%]**	**Mass [kg]**	**Share [%]**	**Mass [kg]**	**Share [%]**	**Mass [kg]**
Pine timber	56,0	43,3	53	37,6	24	12,2	21	11,5
Glazing	39,1	30,2	42	29,5	51	26,1	50	27,3
Aluminum	0,0	0,0	0	0	7	3,4	7	4,1
Steel	3,9	3,0	4	2,8	16	8,3	5	2,8
Plastic	0,0	0	0	0	1	0,5	1	0,4
Rubber	0,4	0,3	0	0,3	0	0,2	1	0,3
Preservation	0,5	0,4	1	0,4	1	0,5	1	0,4
Glue	0,0	0,001	0	0,001	0	0,001	0	0,001
Composit	0,0	0	0	0	0	0	15	8
Paint	0,0	0,03	0	0,02	0	0,02	0	0,02
Total	100	**77,3**	100	**70,7**	100	**51,3**	100	**54,8**

*After tightenig air leakage

Six different scenarios is evaluated and compared: S1a - Life time of 60 years, S1b – Life time of 60 years and sealing after 20 years, S2 – Life time of 30 years (1980 modell installed in 1990), S3 – Life time of 20 years, S4 – Life time of 10 years (change to new improved window technology when this is avaliable) and S5 (Theoretical) - 2010 technology, double price, life time of 60 years. All five scenarios are simulated two times considering the scenario both with exhaust and balanced ventilation in the climate of Oslo, Norway. As a

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demonstration of the improved energy efficciency in the period, a window of 2010-performance and 60 years lifetime was included for comparison.

Costs are estimated using statistical electricity price data for each year since 1960 [19] and discounted window costs with reference year 2010. In 2010 a regular window cost 487.6 Euro [20] using exchange rate dated 19.05.14. An extra cost of 50 Euro was assumed when reducing heat loss (S1b). Discount rate used is 4%.

Results

Figure 1 show how the proportions of buildings having partially replaced or totally replaced windows vary with building age. For the purpose of this study it suffices to note that 38-40 years is a reasonable estimated service life, but with large variation, and indications that life time expectancy probably has changed through the period.

Figure 2 and Figure 3 shows non-renewable primary energy need per year and total costs for the different life time scenarios. Figure 2 indicates that in the climate of Oslo, the lifetime non-renewable energy consumption would be lower with a service life of 10 years than 20, 30 or 60. The technological progress in energy performance of windows makes up for the embodied energy related to extra material input. It is shown that the embodied energy does only count for about 6% of the total non-renewable primary energy need in S4, and it is about 20% difference in primary energy use between S1a and S4. If 2010-technology was installed in 1960 (S5), energy savings of about 50% could have been achieved.

Balanced mechanical ventilation increases the energy consequences of airtightness.

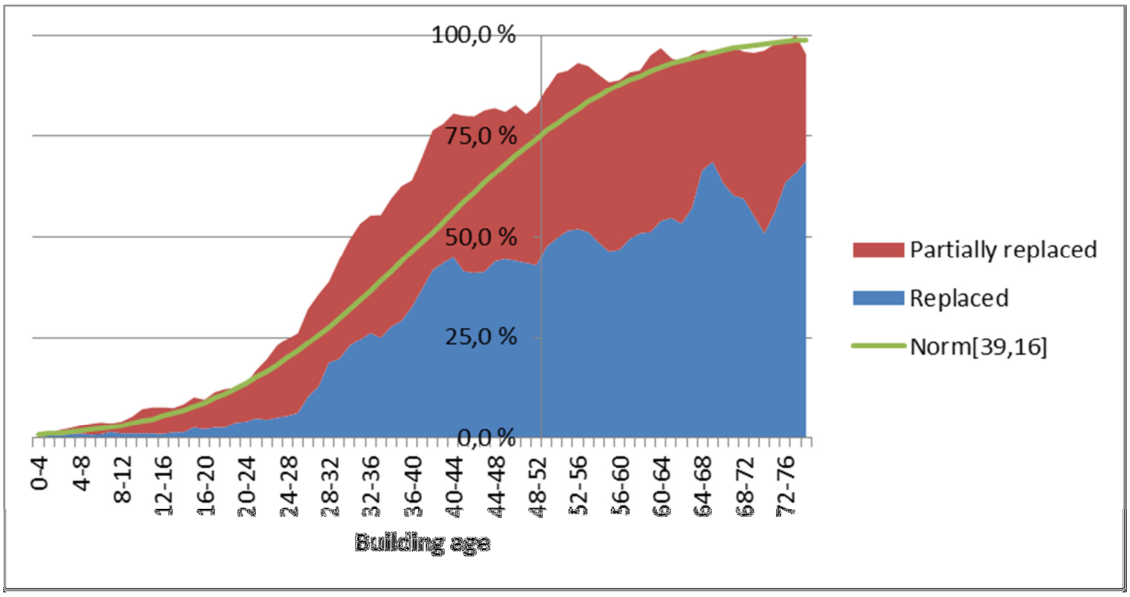

Figure 1: Proportion of buildings of different age with replaced or partially replaced windows (4 year moving average). Y-axis crosses at the category corresponding to the reference year 1960. Normal probability distribution with μ=39 and σ=16 shown for comparison.

When it comes to life time costs (Figure 3), these are lowest with a service life of 60 years and highest with a life time of 10 years However, the life time energy costs are sufficiently

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high to defend a higher initial investment in better energy performance. In S5 a price of 2 times the initial 1960-price was assumed, but increasing this up to 2.3 makes S5 equal to S1a.

The analysis is sensitive to climate, investment costs and electricity prices.

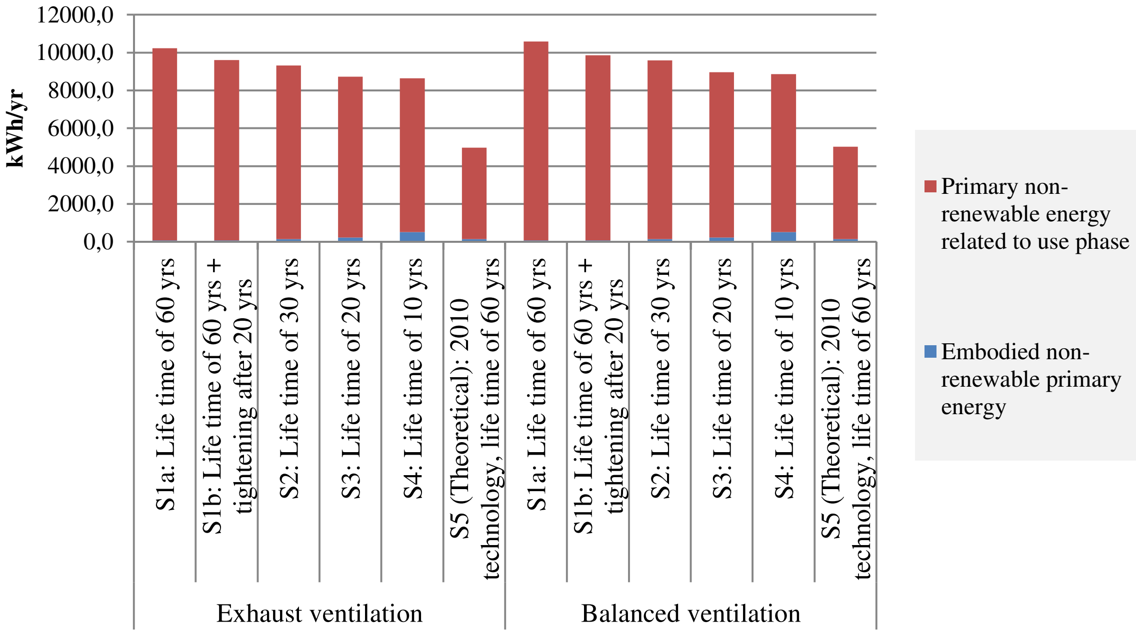

Figure 2: Annual non-renewable primary energy for the different scenarios

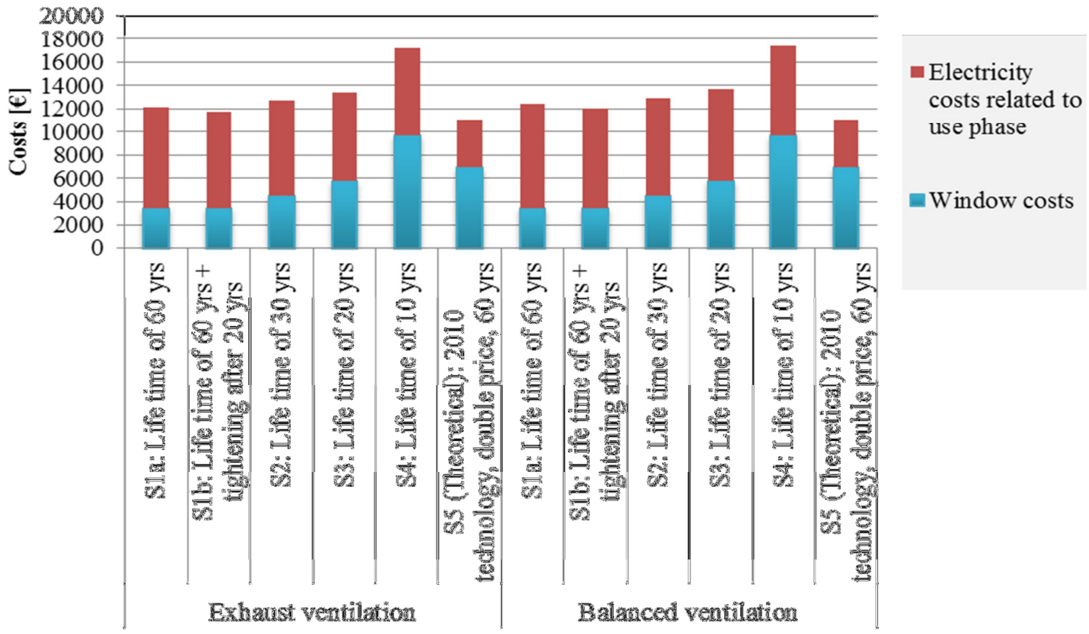

Figure 3: Total costs for the different scenarios

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Discussion

The estimated median service life of 38-40 years in this study is comparable with estimates by [21] of about 40 years for timber windows and about 47 years for a timber window with alu-clad and [22] of 45 years. It may be more likely that one or two windows in a building are changed, than that the majority, but not all, are changed. Since our method did not take the proportion of changed windows in each dwelling into account, our estimate may be biased towards a shorter life expectancy. Also the relative large proportion of assessment reports with missing or contradictory data may be a source of bias.

[23] considered the influence of maintenance levels on the design life and durability of different types of timber framed windows. The results argue that with the right type of maintenance, the service life time for timber-framed windows could be 56-80 years and for timber framed with alu-clad 71-83 years. Since we have not incorporated the reason for changing windows into our study, further studies are needed to conclude if our seemingly much shorter service life is due to windows being changed from "non-technical" reasons, or if it is related to differences in quality and condition between our material and that of Menzies.

In our calculations we have used the values of the previous class of windows in the calculation that involves replacements in intermediate years (1970 and 1990). If the technological development was more continuous than stepwise, the energy consumption of the scenarios with shorter service lives would be even lower than calculated in our model. The lack of good environmental data from window production in the period has prevented a more thorough analysis on life-cycle environmental impact, and concidering other environmental effects, e.g. the use of wood preservatives in timber frames, PCBs in window panes etc. might lead to quite different conclusions than those based solely on non-renewable energy.

The costs related to removing existing and installing new windows will vary a lot depending on location, access, wall construction and window type, but no good estimates were found.

Conclusions

Based on condition data from 2899 Norwegian dwellings, the expected service life of windows was estimated to be at 38 years, in accordance with commonly used estimates. The variation in service life indicated that technological development in the period affected both performance and service life.

In Oslo climate, the energy impact was lowest, with a service life of 10 years, while a 60 year service life was the most economically beneficial. However, life time energy costs are sufficiently high to defend a higher initial investment in better energy performance. The analysis is sensitive to climate, investment costs and heating prices.

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A scheme for the energy performance and rating of windows in Europe

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Abstract: *The paper attempts to propose a new system for assessing the energy performance of the windows at a pan-European level, taking into account both the heating and the cooling needs. In order to propose a new rating system which can be applied across Europe, climatic zones were defined on the basis of cooling- and heating- degree days. A detailed analysis of the energy performance of the windows on every proposed climatic zone of Europe followed, conducted as the dynamic simulation of the energy needs of a reference building unit encompassing a number of window alternatives, which differentiated with regard to the geometrical, the thermal and the optical characteristics of the window, as well as the orientation and the use of the reference room used for the analysis. Based on the results, a rating system for the energy performance of windows was developed, which can be used for the categorization of the fenestration products based on their thermal and optical characteristics for different orientations and for every climatic zone of Europe.The merit of the current paper is that it provides an approach for rating the energy performance of windows at a European level, not only by assessing their contribution on the formation of heating loads, but also by taking into account their involvement into the cooling needs. By combining these two components of window energy performance, the selection of energy-efficient windows will be promoted, given the fact that for a significant part of Europe cooling has an equally important role in the building's energy balance.*

Energy performance, fenestration, energy performance index

Introduction

Towards the accomplishment of the 20-20-20 targets set in the recast of the European Directive on the energy performance of buildings, the building's sector provides many opportunities for action, since it is the largest user of energy and CO_2 emitter in the EU. The impact of windows, fenestration and glazed structures on the building performance is significant, not only because the heat transfer through windows accounts for a substantial proportion of the building consumption, but also because they combine many vital functions of the building, which ask for properties that are usually conflicting and time variant, both diurnal and seasonal. The energy rating and labeling of windows provide consumers and engineers with the simple, straightforward information they need in order to make energy efficient decisions, facilitating thus the implementation of the Directive.

There is ongoing work in several countries with the aim of establishing a system for energy rating and labeling of windows, which would indicate the possible savings of an advanced window compared to a standard one. Currently, USA, Canada, Australia, New Zealand, Great Britain, Sweden, Finland, Denmark, Slovakia and the Czech Republic have adopted systems for energy rating of the fenestration products [1]. Among them, only Australia and New Zealand have taken into account the cooling performance. It is worth mentioning that similarities appear on the rating and labeling schemes found in each continent; for instance, in

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USA and Canada the windows are labeled with regard to their thermophysical and optical properties; energy efficient products are marked with Energy Star. For the countries of Oceania, the windows energy performance is assessed through the impact of the examined window type on the heating and cooling needs of a typical house. By comparing these values with the ones derived for the reference window type (single glazed aluminum window), heating and cooling stars are attributed and the percentage reduction on energy needs is indicated. In most European countries with an existing window rating scheme, a formula is usually used for calculating the energy balance at the level of the window or on the basis of a reference building; the formula employs the thermal and solar transmittance of the window and occasionally the infiltration attributed to the window. Along with the similarities on the calculation method, all existing schemes share the same philosophy as regards the label appearance, which obviously follows the EU energy label for white goods.

Based on these facts the idea for developing an energy rating and labeling scheme for windows that could be used all over Europe seems reasonable; the scheme will have to propose the energy parameters and the calculation methodology, upon which the rating will be based. The applicability of the rating scheme in Europe can be assured by the establishment of climate zones in the region, as well as by employing both heating and cooling energy performance as criteria in the proposed methodology.

Calculation methodology

The energy performance of windows was assessed through the calculation of the window energy index, q_w, which represents the energy contribution of the rated window to the formation of the energy balance of a reference building unit. It is calculated as the difference between the annual energy needs of the reference room with the examined window system, Q_w, and the annual energy needs of a notional room, which is identical to the reference one, but its window is adiabatic (U=0) and non transparent to solar radiation (g=0), Q_{w,no_win}, divided by the window surface A_w [2-4]:

$$q_w = \frac{Q_w - Q_{w,no\_win}}{A_w}$$

It is possible to use the aforementioned parameter in order to characterize the heating or the cooling performance of the window; in that case the energy needs calculated for the presence, Q_w, and the absence of the window, Q_{w,no_win}, are substituted by the respective amounts denoting the heating (Q_h, Q_{h,no_win}) or the cooling demands (Q_c, Q_{c,no_win}) of the reference unit. In every case, the energy needs of the reference unit are calculated with the help of Energy+, an energy analysis and thermal load simulation program for detailed dynamic calculations.

The reference room, the geometry of which is defined in EN 15265 and ISO 13790, is of rectangular plan, 3.6m wide and 5.5m long, with a storey height of 2.8m. This configuration was selected as it was assumed that both an office and a residential building could be formed by the multiplication of the reference unit. For the analysis, all opaque building components were regarded as adiabatic, with the exception of the front wall, which was regarded as thermally insulated with a 0.05m layer of EPS (λ=0.04 W/(m K)) positioned externally.

For the analysis the profiles of residential and office usage were taken into account; however, in this paper only the results produced for the office use are presented, due to the restricted space. As an office, it was assumed that the building unit is occupied during the working days of the week (Monday to Friday) from 07:00 till 17:00 all year long. Only during this operating time the HVAC systems are in operation. The cooling and the heating set-points were considered equal to 24.5^{o}C and 22^{o}C, in accordance with EN 15251 [5]. Internal loads were regarded equal to 132Wh per day, which account for 13.76W/m² during the operating time and 2 W/m² for the remaining time. Ventilation varied from 0.8ACH to 1.50ACH for Mediterranean countries, while for the rest of the Europe it was considered equal to 0.50ACH. The infiltration was considered equal to 0.50ACH for the Mediterranean counties, due to the increased air permeability, and 0.2ACH for the rest of Europe.

For the multiparameter analysis alternative scenarios were studied, which differentiated mainly on the fenestration properties and the façade's characteristics. As regards the fenestration properties, window products with different thermal and optical properties with respect to their frame fraction were studied. The selected values for the thermal transmittance of the window U (Table 1) cover a wide range of conventional and advanced fenestration systems; they range from 0.72W/m²K (passive window) to 3.20W/m²K. Both high (e.g. 0.76) and low (e.g. 0.30) values of the solar transmittance of the glazing g_{gl} were taken into account for each window (apart from the passive window). The solar transmittance of the whole window depends on the area of the transparent element; therefore the changes on the frame fraction from 10% to 30% resulted in different values of g.

As regards the façade's characteristics, different window sizes and orientations were studied. It was assumed that the window was positioned on the main façade of the room and covered 10%, 25%, 50%, 75%, 90% and 99% of the façade. It was also assumed that the window and the façade faced the four cardinal orientations, i.e. South, North, East and West.

The parametric analysis described above was performed for 15 cities, which were selected as the most representative of the northern, the continental and the southern part of Europe with regard to the climatic characteristics [6]. More specifically, for the coldest zone, the climate files of Aberdeen, Berlin, Stockholm, Tampere and Warsaw were included in the analysis. The continental Europe was represented by Belgrade, Bilbao, Brussels, Madrid and Milan, while the mediterannean regions comprised Athens, Larnaca, Lisboa, Malaga and Rome. The climatic data were retrieved from the extensive database of meteorological information of Energy+. It is worth mentioning that for the office occupancy the results of 9720 simulations were used in the analysis, which accounts for 3240 cases for each climatic zone and 648 for each examined city, resulting to a reliable and consistent sample.

Table 1. The thermophysical and the optical properties of the windows used in the analysis.

Window type	**U-window [W/(m²K)]**	**g-glazing [-]**

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Type 1	3.20	0.76
Type 2		0.30
Type 3	2.60	0.76
Type 4		0.30
Type 5	2.00	0.67
Type 6		0.30
Type 7	1.37	0.60
Type 8		0.30
Type 9 (passive window)	0.72	0.40

The multiparameter analysis allowed for identifying the contribution of each window type to the energy balance of the reference unit, which resulted in assessing its performance under different climatic conditions, orientations and properties. A statistical analysis followed, which aimed firstly at detecting the parameters with the most significant impact on the energy index of the window and secondly at developing mathematical formulas that can be used for predicting the energy index of the window based on the window properties. Finally, through the implementation of these formulas, the rating scheme of the windows was generated.

Assessing the energy performance of windows

The extensive parametric analysis offered a plethora of significant results, which mainly focused on the contribution of the window's characteristics on the energy balance of the reference unit regarding the heating and the cooling needs. This contribution was found to differentiate substantially among the climate zones, the orientation and the window geometrical, thermophysical and optical properties.

More specifically, it was found that the window energy index ranges in higher values for the northern regions. As expected, the contribution of the window to the formation of heating needs dominates, resulting to even higher values for the heating energy index of the window. On the contrary, the cooling energy index calculated for the Northern European regions has a noticable value only for the cases of windows with high g-value. Similar findings are observed for the continental Europe, though at a less significant extent; the values of the window energy index are distributed across a narrower range, and their heating components are much higher than the cooling ones. The picture is altered for the Mediterannean regions: although the energy index of the window values are scattered within the range found for the continental Europe, the values for the heating energy index are low and are distributed close to the x-axis. On the contrary, the cooling energy index reaches much higher values and practically determines the overall performance of the window in these areas.

Interesting results have also been derived with regard to the orientation of the transparent element. For all climates the windows that are orientated due North have the maximum contribution to the formation of heating needs and the minimum to the formation of cooling needs. Due to the great differences on the climatic conditions among the examined sites, the overall impact of the northern windows on the energy balance of the reference unit differentiates: in heating dominating climates, such as those of northern and continental Europe, the windows that are orientated due north have a significant impact on the determination of energy demands, while in cooling dominating climates, such as of the mediterannean regions, the northern windows perform better, especially when the solar transmittance of the window is high. For all climates the south orientated windows have an enhanced performance, which is highly dependent on their surface, due to their important role on determining the energy flows as solar heat gains and as thermal heat losses towards the ambient environment. Again, this is more obvious in the mediterannean sites, especially for the cases of windows with a low g-value. Eastern and western windows have a similar performance; their energy index values range in high levels for the cooling dominating sites.

As regards the window properties, it is derived that for all regions the windows with lower thermal transmittance are characterized with lower values of heating energy index, which is favourable. However, the values of cooling energy index resulting for these windows are increased and actually have a considerable effect on the overall performance of the window when the solar transmittance of windows is increased. This practically means that when the building design objective is the minimization of heating loads, low U-values and high g-values are preferred, while in the case that the minimization of cooling loads is seeked, a high U- value and a reduced g-value of the window are favourable. For the overall energy performance, which is usually the objective, the guidelines differ with regard to the climate characteristics; for heating dominating climates attention should be given to the limitation of thermal losses, which is achieved through windows with low thermal transmittance, while for cooling dominating climates the limitation of solar gains and the increase of thermal flows towards the ambient environment in summer is achieved with windows with a moderate to high thermal transmittance and a low solar transmittance.

Predicting the energy performance of windows

From the findings presented synoptically above it is easily deducted that the energy performance of window varies significantly with regard to the climate conditions, as well as the orientation and the properties of the window. Additionally, it may be useful to discern between the heating and the cooling energy index of the window, since it has a different impact on the heating and cooling building performance. These general findings were employed in the statistical analysis for developing formulas that could express the energy performance of windows. In order to achieve higher accuracy, it was regarded necessary to develop different formulas for each climate zone and each orientation, which would be used in order to calculate the energy index, the heating energy index and the cooling energy index of the window, based on its thermophysical and optical properties, i.e. the parameters that play the most important role for determining the window energy performance.

Analysis showed that in all cases the most appropriate model for all formulas is of the form $q_i = a + b \times U_w + c \times g_w$, where q is the energy index of the window; i stands for w, for the overall performance, h, for the heating performance and c, for the cooling performance; U_w is the thermal transmittance of the window; g_w is the solar transmittance of the window; a, b and c are the coefficients derived from the statistical analysis for each formula, given in Table 2 together with the values of the coefficient of determination R^2 for each equation.

Table 2. The coefficients a, b c of the equations developed for predicting the energy index of window q, the

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heating energy index of window q_h and the cooling energy index of window q_c for the three climatic zones of Europe and the four cardinal orientations.

Zone	North orientation			East orientation			South orientation			West orientation		
Norhtern	**q**	**q_h**	**q_c**	**q**	**q_h**	**q_c**	**q**	**q_h**	**q_c**	**q**	**q_h**	**q_c**
a	6.89	1.79	5.10	8.39	-0.51	8.90	-1.43	-10.34	8.91	9.10	-1.34	10.44
b	122.43	131.36	-8.93	109.32	125.94	-16.62	102.51	122.99	-20.49	109.72	126.50	-16.78
c	-89.15	-141.36	52.21	-30.16	-193.06	162.90	-104.29	-314.68	210.39	-37.41	-194.91	157.49
R^2	0.84	0.85	0.66	0.80	0.87	0.65	0.71	0.89	0.71	0.81	0.88	0.67
Continental												
a	6.13	1.62	4.50	13.27	0.58	12.69	1.76	-8.52	10.28	15.40	0.05	15.35
b	72.18	86.95	-14.77	59.58	81.99	-22.41	47.72	75.72	-28.00	59.69	82.66	-22.98
c	3.66	-120.76	124.42	138.21	-173.75	311.96	80.49	-264.89	345.38	126.79	-173.46	300.24
R^2	0.75	0.81	0.75	0.66	0.77	0.64	0.45	0.70	0.70	0.68	0.77	0.68
Southern												
a	5.59	3.18	2.42	9.66	-2.58	12.24	-19.27	-17.66	-1.61	14.56	-1.36	15.92
b	34.35	45.23	-10.88	19.20	38.64	-19.44	3.29	30.12	-26.83	21.41	40.42	-19.01
c	84.18	-104.75	188.92	361.96	-157.97	519.92	367.57	-187.96	555.53	307.82	-153.61	461.43
R^2	0.86	0.81	0.80	0.80	0.79	0.83	0.40	0.50	0.74	0.67	0.82	0.71

Rating the energy performance of windows

In general, there is no standardized procedure for defining the limits of the energy categories. In order to propose a rating scheme, a basis for the comparison of the window performance should be formed. Given that the examined fenestration types are regarded as representative to those met in the European constructions, it is logical to categorize their performance with regard to the best (lowest q) and the worst (maximum q) behavior. Within this context, the minimum and maximum values of q, q_h and q_c of all window types were retrieved and their difference was calculated ($d=q_{max}-q_{min}$). The calculated value d was divided to three, in order to create 4 main categories; the borders between the rating categories were set by adding d/3, 2d/3 and d to the q_{min}. The derived limit values between the rating categories are presented in Table 3. Following this approach, more categories could have been formed. The proposed scheme can be used for the assessment of the energy performance of a window by applying the coefficient values presented in Table 2, taken into account the properties of the examined window and the climate zone that it is going to be installed. The resulting value will be used for labeling the examined window via the limits presented in Table 3.

Conclusions

In this paper a proposal for the rating of the energy performance of windows in Europe is presented. It involves simplified formulas for the calculation of the energy index, as well as the establishment of the cooling energy categories for the rating scheme. The detailed analysis showed that the rating should be based on the thermal and solar transmittance of the windows. Additionally, it was regarded necessary to determine the window performance not only with regard to the climate, but also with regard to the orientation of the window and the building use. The merit of the current paper is that it provides an approach for rating the energy performance of windows at a European level, not only by assessing their contribution on the formation of heating loads, but also by taking into account their involvement into the cooling needs. By combining these two components of window energy performance, the selection of

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energy-efficient windows will be promoted, given the fact that for a significant part of Europe cooling has an equally important role in the building's energy balance.

Table 3. The limits between the categories for rating the energy index of window q, the heating energy index of window q_h and the cooling energy index of window q_c for three climatic zones of Europe and the four cardinal orientations.

Zone	**North orientation**			**East orientation**			**South orientation**			**West orientation**		
Norhtern	**q**	**q_h**	**q_c**	**q**	**q_h**	**q_c**	**q**	**q_h**	**q_c**	**q**	**q_h**	**q_c**
A+	<31	<23	<-6	<31	<6	<-6	<17	<-18	<-6	<37	<-52	<-5
A	137	138	5	126	121	21	107	100	31	130	53	23
B	242	254	16	221	237	47	197	217	69	222	157	51
C	348	369	28	316	352	73	287	335	106	315	262	80
D	454	485	39	411	467	99	377	452	143	407	367	108
E	>454	>485	>39	>411	>467	>99	>377	>452	>143	>407	>367	>108
Continental												
A+	<30	<10	<-8	<38	<-4	<-2	<29	<-25	<-3	<47	<-57	<2
A	90	88	15	99	73	46	79	51	57	113	12	54
B	150	166	37	160	150	93	130	127	117	179	80	106
C	210	244	60	222	226	140	180	203	178	246	149	158
D	270	322	83	283	303	187	230	279	238	312	217	210
E	>270	>322	>83	>283	>303	>187	>230	>279	>238	>312	>217	>210
Southern												
A+	<27	<-1	<4	<44	<-17	<18	<31	<-39	<15	<54	<-63	<26
A	66	42	36	100	24	90	91	1	108	116	-29	102
B	106	85	68	156	64	162	151	40	201	177	5	179
C	146	127	100	213	104	234	211	79	294	239	38	256
D	185	170	132	269	144	306	271	118	387	301	72	332
E	>185	>170	>132	>269	>144	>306	>271	>118	>387	>301	>72	>332

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The Effects of Light Shelf on Climate-based Daylight performance in Tropics- A Case Study

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Abstract: *This paper aims to assess the effects of light shelf on climate-based daylight performance in tropical office buildings. A systematic approach toward assessing daylight performance is presented. The approach is exemplified using the case study of two selected offices in CREATE Tower, an air-conditioned office building located in Singapore. Thereby, a set of variants was generated based on four investigated configurations and then compared. This study contributed to the assessment of the daylight performance and prediction of the consequences of retrofitting alternatives towards fostering the utilization of daylight in existing buildings in the Tropics.*

Keywords, Daylighting, Performance simulation, Dynamic metrics, Passive design strategies, Tropical climate

Introduction

Light shelf has been commonly considered as an effective passive design strategy to reduce the need for artificial lighting and to enhance visual comfort in buildings. Specifically in Singapore, the sun is almost directly overhead throughout the year since this tropical city-state is located in the equatorial belt. Thus, compared to temperate climate, it has more potential to utilize the daylight to supplement artificial lighting and to achieve a more sustainable built environment. Nowadays, a number of more elaborate dynamic daylight metrics have been proposed [1-3] which could allow us to evaluate the climate-based daylight performance in buildings. In this context, this paper presents a preliminary assessment of the effects of light shelf on climate-based daylight performance for tropical office buildings. We first evaluated an array of current daylight performance metrics. Both static and dynamic daylight metrics are considered. Subsequently, a systematic approach toward assessing daylight performance based on above-mentioned metrics is presented. The approach is exemplified using two selected offices (Area A and B) in an existing air-conditioned office building located in Singapore. This study contributed to the assessment of the daylight performance and prediction of the consequences of retrofitting alternatives toward fostering the utilization of daylight in existing buildings in the Tropics.

Approach

Description of the case study model: Daylight performance simulation was conducted for two offices (Area A and B) at Level 11 in CREATE Tower, Singapore (see Figure 1and 2). To present the performance study in a structured manner, we use the following notations: "AA" denotes Area A, and "AB" denotes Area B. High ceiling is specified with code "H", whereas low ceiling is specified with code "L". In addition, we refer to the unshaded windows henceforth as "1" and the shaded windows (adorned with exterior/interior shelves) as "2"

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respectively. For each area, four different configurations were then evaluated (i.e., H1, H2, L1, L2, as per Figure 3). Thus, eight variants (AAH1, AAH2, AAL1, AAL2, ABH1, ABH2, ABL1, ABL2) were considered. The information regarding office geometry, building materials, and optical properties of the surfaces for daylight simulation are listed in Table 1. All the variants together with the surrounding urban context were modelled using Google SketchUp and exported to Ecotect and DAYSIM for further daylighting analysis. Also, a set of illuminance sensor points was deployed in AA and AB based on a grid resolution of 1m by 1m at work plane height of 0.8m above the floor. Thereby, having the electric luminaires turned off were considered. However, as the base case study, no shading devices were assumed at this stage. The requirements (involving properties) and effects of the shading devices and interior furniture will be studied in future work.

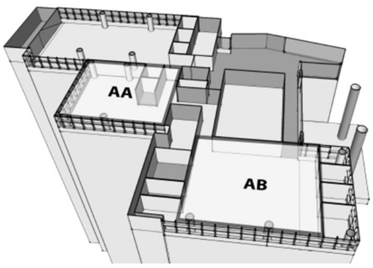

Figure 1 perspective of AA and AB at CREATE Tower

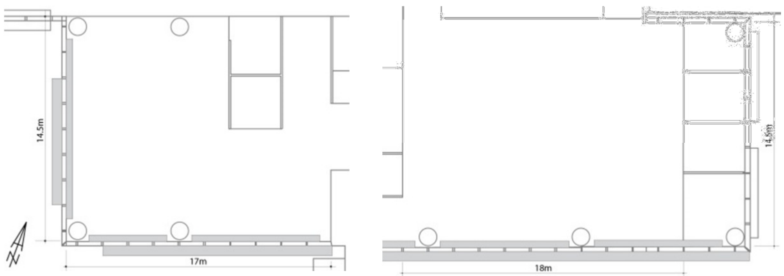

Figure 2 Plan views of AA (a) and AB (b) together with the positions of the exterior and interior shelves.

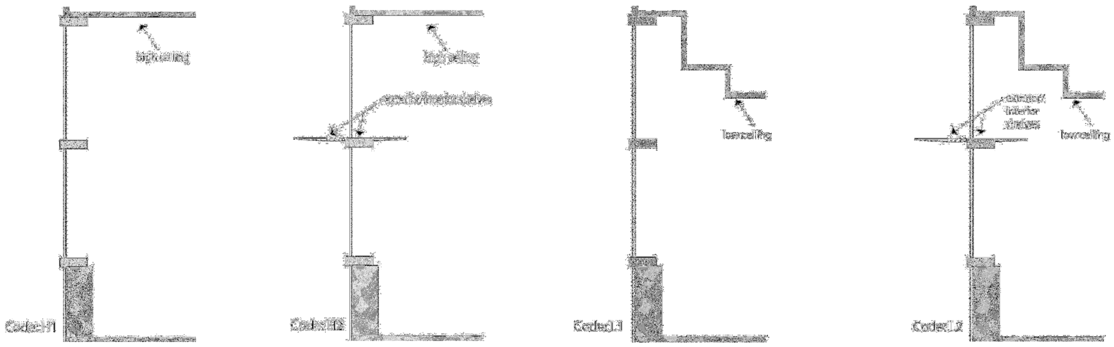

Figure 3 Illustration of four investigated configurations, namely H1, H2, L1, L2

Table 1 Building materials and optical properties

Area Code	AA	AB
Width (m)	17	18
Depth (m)	14.5	14.5
Height (m)	3.72 (high ceiling)/ 2.82 (low ceiling) for both areas	
Window sill height (m)	0.875 for all windows	
Glazing Tvis	0.61 for all windows	
Exterior & interior shelves (m)	0.6 & 0.4 for both areas	

Table 2 Radiance ambient parameters

Parameter	Value
Ambient bounces (-ab)	5
Ambient accuracy (-aa)	0.1
Ambient resolution (-ar)	300
Ambient divisions (-ad)	1000
Ambient super-Samples (-as)	20
Reflectance of shelf surface	0.8 for both areas
Reflectance of ceiling surface	0.7 for both areas
Reflectance of wall surface	0.6 for both areas
Reflectance of floor surface	0.4 for both areas
Reflectance of ground	0.2

Weather File: The weather file used was Singapore (latitude 1.22°N, longtitute 103.59°E), with the ASHRAE International Weather for Energy Calculations (IWEC) data for Singapore,

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WMO 486980 downloaded from EnergyPlus weather data website [4]. The IWEC weather files for Singapore are derived from up to 18 years (1982-1999) of 8760 hourly weather data originally archived at the National Climatic Data Center. The weather data is supplemented by solar radiations and illuminance estimated on an hourly basis from earth-sun geometry and hourly weather elements (e.g. cloud coverage) [5].

Computational Simulation Tools: This study was entirely carried out by simulation using the Autodesk Ecotect Analysis [6], and DAYSIM [7-8]. DAYSIM is a RADIANCE-based day-lighting analysis tool developed by the National Research Council of Canada and the Fraunhofer Institute for Solar Energy Systems in Germany. DAYSIM employs the daylight coefficient method [9] to efficiently calculate illuminance distributions under all sky conditions in a year and using the Perez sky model [10]. The simulations were performed assuming that these two selected offices (i.e., AA and AB) were occupied Monday through Friday from 9:00 to 17:00. The occupant leaves the office three times during the day (30 minutes in the morning, 1 hour at midday, and 30 minutes in the afternoon). The occupant performs a task that requires a minimum illuminance level of 500 lx [11]. For all simulations, ambient parameters in Radiance are set as shown in Table 2.

Performance Metrics For Daylighting: We propose a set of evaluative metrics, whereby both static (daylight factor) and dynamic (daylight autonomy, continuous daylight autonomy, daylight autonomy max, and useful daylight illuminance) are considered (see Table 3). Daylight factor is calculated at single point in time, while dynamic metrics are calculated based on an extended period of time with variable sky conditions on an annual basis. Thus, dynamic metrics could provide more detailed information on daylight performance [3].

Table 3: Metrics conducted to assess daylighting performance in the offices in Tropics

Metric	Criteria	Description	Reference
Daylight factor (DF)	<2%	Gloomy appearance with rare daylight. Electric lighting needed during daylight hours.	[2,9,12]
	2%-5%	Predominant daylight appearance. Some supplementary electric lighting required.	
	>5%	Daytime electric lighting rarely needed. Thermal/glare issues may occur along with the high levels of daylight.	
Daylight autonomy (DA)	--	The percentage of the occupied period (hours) of the year that the minimum daylight requirement is exceeded through the year.	[1,3,13]
Continuous daylight autonomy (DAcon)	>80%	Excellent daylight designs.	[1,13]
	60-80%	Good daylight designs.	
	40-60%	Adequate daylight designs.	
Daylight autonomy max (DAmax)	>5%	Not acceptable. A high probability that this will lead to a situation with a direct sunlight patch and hence glare.	[1]
	<5%	Acceptable.	
Useful daylight illuminance (UDI)	<100 lx	Gloomy room with insufficient daylight.	[16,17]
	100-2000 lx	The room is with useful daylight levels for the occupants.	
	>2000 lx	The room is too bright and exceeds the upper threshold of the useful range. Higher levels glare or discomfort may be delivered together with overheating issues.	

i) Daylight Factor (DF): Daylight factor (DF) is the most widely conducted metric for daylight performance in buildings [3]. It is the ratio of internal light level at one point in a

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building to the unshaded external light level under the Standard CIE overcast Sky [2,9,12]. DF is moment-in-time based metric and used in building design for assessing the daylight availability as perceived on the working plane based on the occupants' work activities.

ii) Daylight Autonomy (DA): Daylight autonomy (DA) is the simplest and most widely conducted annual metric. It is generally defined as the percentage of the occupied period (hours) of the year that the minimum daylight requirement is exceeded through the year. Such metric as DA could be employed to address the spatial daylight distribution for further analysis [1,3]. The main advantage of DA over the DF is that it takes facade orientation and user occupancy profiles into account and considers all possible sky conditions [13].

iii) Continuous daylight autonomy (DAcon): A modified metric "continuous daylight autonomy" (DAcon), based on DA, attributes partial credit to time steps when daylight illuminance lies below the minimum illuminance level [14]. For example, in the case where 500 lx is required and 300 lx of daylight is received at a given time step, a partial credit of 300 lx/500 lx=0.6 is attributed for that time step. Thus, the metric acknowledges that even a partial contribution of daylight to illuminate a space is still beneficial.

iv) Daylight autonomy max (DAmax): To simultaneously consider the potential appearance of glare, an indicator called daylight autonomy maximum (DAmax) was also proposed [14]. DAmax compiles the percentage of times during a year when the illuminance at a sensor is at least 10 times the recommended illuminance. For instance, for an office space with a design illuminance of 500 lx DAmax corresponds to 5000 lx [1]. As such, this will mostly correspond to a situation with a direct sunlight patch at the sensor and hence glare [15].

v) Useful daylight illuminance (UDI): Useful Daylight Illuminance (UDI) is another modified version of Daylight Autonomy [16,17]. This metric complies the number of operating hours based on three illuminance ranges, namely 0-100 lx, 100-2000 lx, and greater than 2000 lx. Useful daylight is considered to occur when the daylight illuminance fall into the range of 100 lx and 2000 lx [3]. Thus, it provides full credit only to values between 100 lx and 2,000 lx suggesting that horizontal illumination values outside of this range are not useful.

Results

A study of daylighting performance for AA and AB using a set of simulation tools (i.e. Ecotect and DAYSIM) was carried out and generated an extensive quantity of data. The data was analyzed, some of which are presented in below.

Table 4 shows the simulation results of eight specified variants (i.e., AAH1, AAH2, AAL1, AAL2, ABH1, ABH2, ABL1, ABL2) in accordance with the previously described daylight performance metrics, namely daylight factor (DF), daylight autonomy (DA), Continuous daylight autonomy (DA_{con}), Daylight autonomy max (DA_{max}), and Useful daylight illuminance (UDI). Note that the simulation results were calculated based on the mean values. To provide a series of dynamic daylight performance analysis for these eight variants, metrics such as DA_{con} (see Figure 4), DA_{max} (see Figure 5), and UDI (see Figure 6) were conducted

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respectively. Figure 4 depicts the DA_{con} with 500 lx specified as the DA threshold ($DA_{con}500$) and the percentage of the space exceeding 500 lx over 40%, 60%, and 80% of the time on an annual basis. Figure 5 shows the percentage of the space exceeding 10 times the illuminance threshold (500 lx) over 5% of the time on an annual basis. In an effort to compare the UDI metric in these eight variants based on the UDI criteria (illuminance range: less than100 lx, in the range of 100 and 2000 lx, and greater than 2000 lx) is presented in Figure 6.

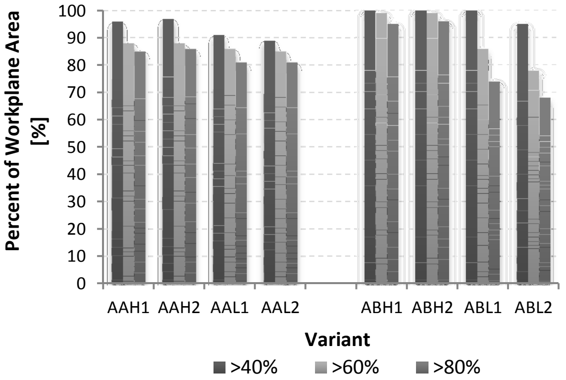

Figure 4 The percentage of workplane area above 40%, 60%, and 80% DAcon (500 lx)

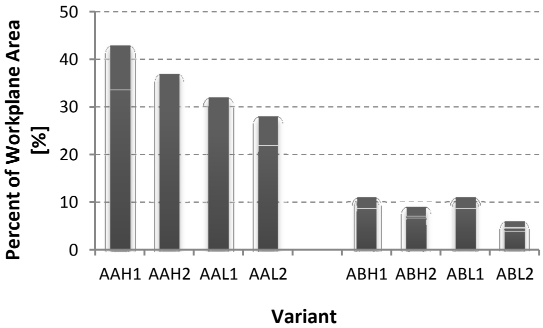

Figure 5 Percentage of workplane area above 5% DAmax

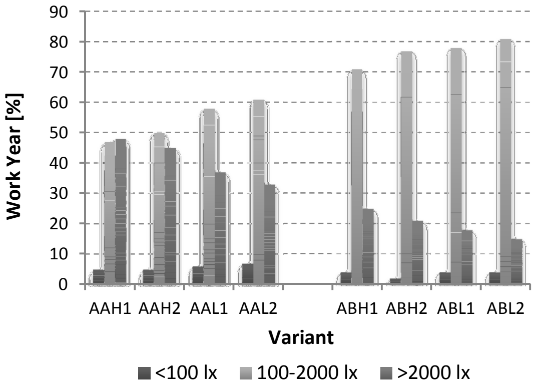

Figure 6 UDI (mean values, %) for eight variants, based on three illuminance range: less than100 lx, 100 lx to 2000 lx, and greater than 2000 lx

Table 4: Simulation results of eight variants, (%)

Code	AA H1	AA H2	AA L1	AA L2	AB H1	AB H2	AB L1	AB L2
DF	5	4	4	3	4	3	3	3
DA	81	81	75	73	84	82	64	57
DA_{con}								
>40%	96	97	91	89	100	100	100	95
>60%	88	88	86	85	99	99	86	78
>80%	85	86	81	81	95	96	74	68
DA_{max} >5%	43	37	32	28	11	9	11	6
UDI <100	5	5	6	7	4	2	4	4
UDI 100-2000	47	50	58	61	71	77	78	81
UDI >2000	48	45	37	33	25	21	18	15

Discussion

The simulation results support a number of initial conclusions, as discussed in the following two sections, namely daylight quantity and quality.

Daylight Quantity: The simulation results show all the variants offer predominantly daylight appearances that can provide sufficient ambient lighting for the majority of the year (see Table 4 and Figure 4). According to the DF metric, these eight variants meet the DF (2%-5%) criteria. Moreover, DA_{con} (>60%) reveals that these eight variants deliver high uniformity of daylight throughout the spaces with greater than 80% of the space obtaining continuous daylight autonomies over 60 percent. On the other hand, as DAcon (>60% and >80%) shown in Figure 4 imply, there are variants (particularly ABL1 and ABL2) with passive design

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elements (i.e. low ceiling and exterior/interior shelves), which, while increasing in complexity, give relatively lower levels of daylight appearance.

Daylight Quality: The results clearly show that higher percentage of workplane area in AA receives direct sunlight than in AB (see Table 4, Figure 5, Figure 6). This difference may be attributable to the building layout design, that more direct sunlight may deeper penetrate into AA (from the fenestrated southwest and southeast oriented facades) than into AB (from the fenestrated southeast oriented facades). Thus, the variants in AA are with less useful daylight level and more prone to glare. Specifically, UDI (>2000 lx) of 48% and DAmax of 43% raise a warning flag for Variant AAH1, which has a significantly brighter daylight appearance than the other seven variants. This implies that, strong potentials of glare and discomfort issues may occur in such space together with overheating effects. On the other hand, the results (see Figure 5 and 6) appear to suggest that the passive design elements (pertaining to low ceiling height and exterior/interior shelves) may significantly block and/or redirect the direct sunlight and thus effectively increase the useful daylight levels for the occupants (particularly in AA). The results also demonstrate that the effect of exterior/interior shelves is significant and as important as the effect of low ceiling height. For example, according to the DAmax metric, AAL2 is superior to the three other AA variants followed by AAL1, AAH2, and AAH1 (see Figure 5). Also, UDI (100-2000 lx) and UDI (>2000 lx) indicate that AAL2 is superior to the worst Variant AAH1 with UDI (100-2000 lx) rising from 47% to 61% and UDI (>2000 lx) decreasing from 48% to 33% (see Table 4 and Figure 6). Conversely, the results express that, in terms of the variants of AB, low ceiling and exterior/interior shelves have relatively low impacts on the probability reduction for discomfort glare (see Table 4 and Figure 6).

Conclusion

In ideal architecture design, the whole building systems (involving interior design and building facade) shall be considered together as a holistic design for optimal building performance and integration. The light shelves could then not only increase daylight distribution but also reduce solar heat gain and glare discomfort [18]. Here, we see some challenges in the design practices. The deficient ceiling configuration (related to interior design) that is commonly applied in later stage of the conventional office building design may lead to the poor effectiveness of light shelves, particularly in ABL2. In order to avoid such design gap, the false ceiling design shall be appropriately considered together with the other building systems in the whole building design process.

In this research effort, we have obtained preliminary results toward assessing the effects of light shelf on climate-based daylight performance based on two types of ceiling configuration in tropics. Also, we demonstrated the process and the generation of a set of computational performance simulation models on the basis of documentation of the building (geometry, construction, systems, operation), occupancy, and external (weather) conditions. Further developments of this study are expected to facilitate a detailed and dynamic daylight performance model, whereby the manual/automated blinds, interior office furniture, and lighting energy usage data are considered. The calibrated models will be then applied to compare and evaluate retrofit and enhancement alternatives (involving building envelope components) in view of building integrity, visual, and energy performance in future stage.

Acknowledgment

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Session 120:

The "other" actor´s role. Why aren't all actors visible?

Chairperson:

Gálvez, Miguel Ángel

Doctor Arquitecto. Profesor Titular Interino. Escuela Técnica Superior Arquitectura Madrid, UPM

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The Only Way Out: Introducing A Gender Perspective For Sustainability

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Abstract: *Sustainability thinking constitutes one of the most important areas of interest within the discipline of architecture. Even though numerous studies have been pursued around this topic, concerns remain about the future of the Earth. A detailed examination of environmental discourses and design approaches taking part within the sustainability paradigm will reveal why these concerns remain. Accordingly, based on the impacts they aim and establish, such approaches could be evaluated in three stages: supporters of the status quo; reformists; and transformationalists. Based on this distinction, opinions which have the potential to trigger this paradigm shift, and thus the necessary transformation of living environments and the Earth's future, are examined within the framework of this article. Another issue the article brings to the front for debate is the gender perspective's contribution to the sustainability discourse. Therefore, the article attempts to offer a gendered perspective to complement the sustainability perspective of architecture, and will make an effort to provide future recommendations on how to achieve a paradigm shift in the practice of architecture. Thus, design practices that ensure the desired sustainable society structure intended to materialize the sustainability paradigm, will be evaluated.*

Keywords, Sustainable architecture, gender perspective, eco-social approach, eco-feminism.

1. Introduction

Ever increasing environmental problems impacting our daily lives have reached a magnitude impossible to ignore. Negative impacts of environmental factors such as global warming, the extinction of species, the depletion of natural resources essential for human life, and population growth on our health and quality of life have reached significant levels. Upon examining relevant studies, it is observed that egalitarian (pluralist) policies have been implemented in the cultural, ecological, economic, health and education sectors. However, problems related to educational and health services, unemployment and housing still persist in urban environments.

Sustainability is a major concern for the architectural community today. Therefore, it is not surprising to see that it now becomes a priority on the agenda of all nations. However, the appearance of sustainability issues in both architectural practice and architectural education has problematic underpinnings. The most important problem is that the concept of sustainability is primarily defined in relation to sustainable development. In our point of view, this diminished the importance and application of sustainable thinking and strategies in both architectural practice and architectural education.

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The study begins with a critique and evaluation about the current situation of the field of sustainable architecture. This is followed by an evaluation of approaches effective within the sustainability paradigm in terms of their eco-centric, techno-centric, human welfare, and equality aspects. Within this framework, an effort will be made to classify trends which support the current situation about which we are critical about, as reformist trends and transformational trends. Based on this literature review, we will also discuss what we will gain from the eco-feminist approach throughout the discourse and design process, and what this approach's impacts will be.

2. A Critique Of Sustainable Architecture

The environmental ethics perspective has a broad spectrum that proliferates into political and scientific ideological areas [1]. Environmental approaches are deeply ingrained within the social and political structure of our existence. This presence has also crept into our faith about our daily life system, decision-making mechanisms, and values. Despite the fact that it has been a primarily sociological approach, the environmental perspective so far has been neither able to be accommodating nor able to produce peaceful solutions [2].

Tim O'Riordan [3] discusses how the environmental movement, which started to gain momentum in the late 1960's to early 1970's, triggered political, social and design movements. Later, the author introduced the 'sustainable development' concept, a concept that became popular with the 1987 Brundtland Report. Concepts in the Brundtland Report such as 'equality', 'participation' and 'future' established the foundation of the sustainability concept, and initiated a debate on the technological and social formations' limits with respect to nature's resources [2]. With a new way of thinking brought into the debate, the concept of sustainability became a much discussed issue throughout the 1980s and 1990s as part of the environmental movement.

However, the word 'sustainability' is a word that can be used in many different contexts. Its meaning can be also 'shaped' to attribute various meanings. People might have different understandings of the concept 'sustainability'. Ecologists, architects, politicians or sociologists may prioritize sustainability goals differently. For example, within this context, an architect may think about high-performance buildings. However, upon examining the concept more closely with respect to architecture, sustainability is much more than just about bricks and mortar. Social sustainability is at least as important as building technologies [4]. Moreover, no matter how technically advanced and conforming to the natural environment a building may be, when considering its environmental impacts, it may not be wrong to state that a building is still an anti-ecological action [5]. This distinction can be observed in O'Riordan's [6] works: environment-centered or technology-centered designs. Approaches that have an environmental focus actually define themselves between these two extremes. Based on this distinction, environment-centered approaches are more focused on nature protection. They also support social equality. The technology-centered approach, however, has the tendency to support more and more existing policies and the economy.

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This situation demands a need to discuss sustainable architecture's position with respect to its relationship with current environmental approaches, and experiment with its repositioning within this context.

3. An Attempt To Reposition Sustainable Architecture

Attempting to develop an approach to environment and design is not possible without an in-depth review of the ecological literature. This section will show how the sustainable architecture movement has been in coincidence with various different environmental approaches. This discussion also provides the opportunity to question the sustainability paradigm discussed above, which in reality is not sustainable, as well as to criticize the design approach.

The literature on sustainability can be evaluated in three stages. Rees [7] defines these three stages as status quo (change can be achieved through current formations), reform (a fundamental reform is necessary, however this is not possible with the present social structure), transformation (the root of the problem lies in economic and social power structures in a way a radical transformation is required). The author maps out two axes, the social-economic and environmental arguments of sustainability. The social-economic axis covers the priority of the environment from low environmental concern through techno-centred to eco-centred [8]. Hopwood et al. [8] evaluated O'Riordan's map based on the debate on weak and strong sustainability. In their discussion on the sustainable development concept, Hopwood et al. focus more on environmental issues rather than on its social-economic implications.

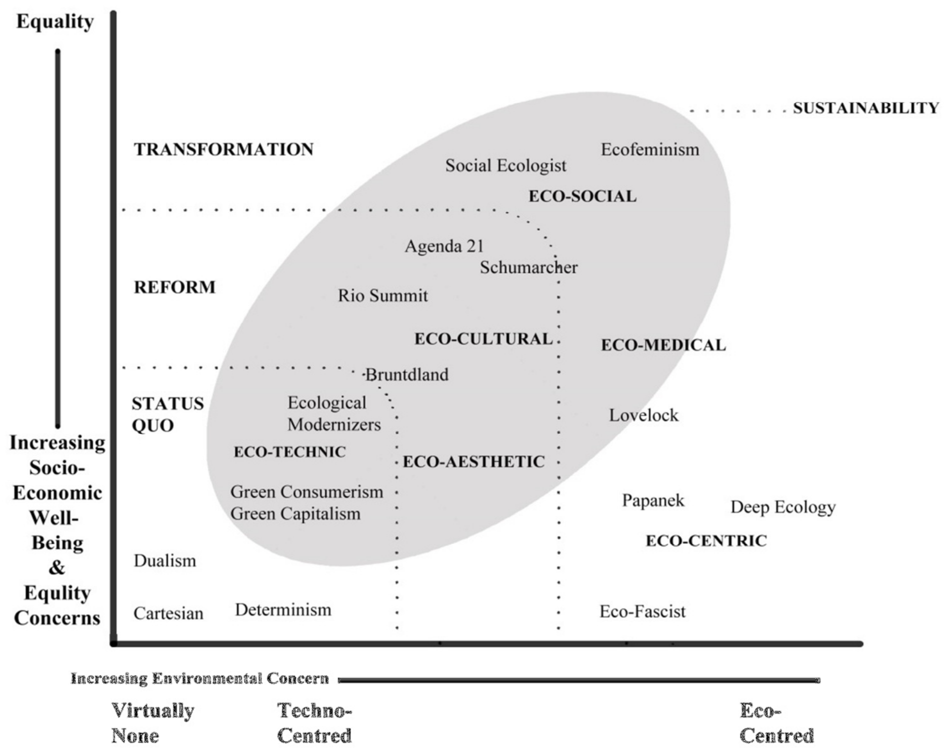

Figure 1: An attempt to reposition sustainable architecture. Based on the work by Hopwood et al. [8] and Guy et al. [9].

An evaluation of Hopwood et al. [8], O'Riordan [6] and Rees' [7] studies in terms of their impacts on the discipline of architecture, resulted in the development of a map as shown in Figure 1. Here, environmental approaches and sustainable architecture discourses proposed by Madge [2], Guy et al. [9] and Fieldson [1] are examined within an attempt to classify environmental arguments of Hopwood et al. [8], O'Riordan [6] and Rees [7]. The purpose of the figure is to reposition current sustainability approaches. It makes it possible to observe in what kind of an area sustainable architectural approaches have manifested themselves. It also shows more clearly the intellectual shifts needed to succeed in the transformation proposed in this article.

Different arguments laid out in this figure, and their consequences within the context of architecture are briefly discussed in the sections below.

3.1. What Do Supporters Of The Status Quo Bring To The Discussion?

The status quo perspective supports a diminished role of government, but supporters are reluctant to use laws and regulations in order to change the system. Elkington and Burke [10] believe that sustainability can succeed with knowledge and life-style choices. They associate their approach to the concepts of green design, green capitalism and green consumption [2]. Their suggestions include profit-aimed approaches they developed for industrial and environmental fields [11].

Even though many ecological modernizers propose the need for reform, they support the current status quo [12]. Therefore, even though status quo supporters advocate for change, they don't recognize neither environmental nor social problems. Supporters of this argument think that necessary regulations can be implemented without fundamental changes in society. In fact, this is the dominant view of public and private sectors, whereby supporters of the status quo work in close cooperation with these sectors.

Upon evaluating the status quo approach with respect to architecture, we encountered a large number of sustainable architecture examples that fall into this category. The architectural approach that dominates this area is eco-technic. Because this approach was developed through technological logic and policy-oriented discourse, it is not surprising that it led to the construction of a large number of products. Like ecological modernizers, architects with an eco-technic approach believe that environmental problems can be solved by relying on science and technology. They strive for energy efficiency, smart buildings and high-tech designs.

3.2. What Do Reformists Bring To The Discussion?

Those who adopt the reformist approach are aware about problems. They also criticize influential politicians, the private sector, and policies developed in line of such trends. However, they do not believe in a possible collapse of the social and environmental system, and any fundamental change. Supporters of this approach do not explore the core of problems

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within today's society. They believe that a change in policies and life-style can happen with today’s social and economic structures [8].

Towards the end of 1980s, developed countries realized that without supporting their neighbors, they will be unable to tackle environmental problems. In the Brundtland Report, prepared by the World Commission on Environment and Development in 1987, ‘sustainable development’ is defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” The Brundtland Report is regarded as reformist. However, although it is regarded as reformist, it takes the current situation as a basis [8].

With the Rio Summit, women became the primary focus of sustainable development policies. In Rio, the wellbeing and education of women was directly linked to the achievement of sustainable development. This shows that women are considered as fundamental for achieving sustainable development. In other, especially in Agenda 21 discussions, the objective was to change constitutional, administrative, cultural, behavioral, social and economic barriers through the participation of women, and thus defining sustainability as a way of achieving success in public purposes [13]. Although the importance of women’s roles in society was highlighted within the context of sustainability both during the Rio Summit and Agenda 21, these meetings did not predict a change with regards to a transformation of social relations.

Reformists like Schumacher place themselves along the line of transformationalists. He argues that the economy is matter of people, and that local and small-scale practices are more sustainable than global and large-scale ones [14].

Evaluating the issue in terms of sustainable architecture, we are confronted with two approaches: the eco-cultural and eco-aesthetic approach.

The eco-cultural approach emphasizes values that are a result of a merging of environmental and cultural relations. Arne Naess [15] stresses that we have the obligation to protect the diversity and wealth of life on Earth, including the diversity of human cultures. Debates around this approach focus on the concept of bioregion. This concept is about the development of design strategies that are in line with the location’s natural, biological and ecological characteristics, as well as its cultural context [9].

The eco-aesthetic approach moves the architectural discourse away from a dimension that is primarily concerned about energy efficiency, targeting ecological footprint reduction. Within the approach there has to be an iconic emphasis on the metaphorical and social values of sustainable architecture. It proposes the need of the art of architecture to develop a new language, and focuses on social transformation. This approach idealizes a new global society and civilization that has ecological awareness and sensitivity, and rejects Western rationalism, modernism and materialism [9]. Even though eco-aesthetics argues that -as a starting point- social transformation is necessary, it does not offer any principles on social transformation, participating in the discussion of more symbolic concerns.

3.3. What Do Transformationalists Bring To The Discussion?

Transformationalists regard human-nature relationships and basic features of contemporary society as the source of the problem. They argue that reform is not enough. Unlike the other approaches, they therefore concentrate on different arguments: Local groups, poverty, the working class and women. Transformationalists focus on the socioeconomic structure as well as the environment aiming to create a social and environmental synthesis [8].

The last transformationalist approach to be mentioned is ecofeminism. Ecofeminism constitutes a combination of different approaches. However, by referring to Platonian and Cartesian descriptions of nature, Plumwood [16] moves the subject to another dimension by discussing how nature and women have been marginalized. Plumwood [16] argues that, because nature is a very broad and varied category, and has also been exposed to different colonizing forms, any appropriate assessment on the domination on nature has to be based to a large extent on the resolution of other forms of oppression and should play a unifying role.

Deep ecologists are primarily concerned about the environment. They strongly emphasize the environment, nature's needs and its intrinsic values. Human needs come second [8]. Some authors argue that such a strong focus on nature, ignoring inequalities among humans, in a way benefits imperialism. Bramwell [17], therefore, draws attention to the connection between fascism and supporters of the Green Party. Besides, not all deep ecologists have a strong focus on the environmental as described above. For example, the owner of the Gaia Hypothesis James Lovelock [18] stresses that the Earth should be regarded as a whole system with a value greater than the collection of its individual parts, and that the environment cannot be divided into parts. These approaches also reject the concept of development.

Within the field of sustainable architecture, an approach that represents deep ecologists is the eco-centric approach. The eco-centric approach benefits from the scientific paradigm of systems ecology. It emphasizes the epistemological integrity implied within ecology, and ecological metaphysical reality. Nature is fragile and can get easily out of balance. Therefore, it brings a radical approach to sustainable architecture whereby building design and construction is questioned. Its approach towards buildings raises concepts of consumerism, parasitic development and pollution. Design objectives of this approach are autonomous, decentralized buildings in harmony with nature, which have limited ecological footprints [9].

Another transformational approach in architecture is the eco-medical approach. Compared to the eco-centric approach, the eco-medical approach has a framework closer to humans. Deeper than cultural frameworks, this approach advocates for social and humanist relationships that foster the continuity of individual health. The approach points to how mechanization accompanied by a risk society threatens the environment. It argues that the sick building syndrome is caused by the weak design of the urban built environment and its mismanagement. The fact that large modern structures remove people from nature, and lessen our ability to control our environment is seen as a major cause of the problem. The goal is natural and tangible spaces so that individuals lead healthy, prosperous and comfortable lives [9].

Another transformational approach is the eco-social approach. This approach claims that there is a dialectical connection between nature and humans. Supporters of this approach argue that approaches to environmental issues are only possible through social criticism and social restructuring. The eco-social approach in architecture builds on Murray Bookchin's [19] definition of social ecology: The ecological principle of unity in diversity grades into a richly mediated social principle. Social ecologists relate the destruction of nature and its suppression to hierarchical structures and dominances within society, and associate such dynamics with the hegemony that one group of people exert on another group. This approach advocates for a decentralized industrial society that constitutes small commune units that have their own productivity. Its building design aspects are reflected by a transparent, flexible and participatory design process that is in compliance with local ecological data [9].

The transformational environmentalist philosophy associates its understanding of sustainability with energy efficiency and the recycling of resource use, along with a fundamental transformation of society and individuals. The sustainability paradigm can only be realized through social sustainability, that is in a social organization that lacks hierarchy, is non-competitive, and respects culture and biodiversity [20].

As can be seen, the sustainability debate expands on a variety of views reflected in a variety of spatial contexts. The goal here was to reflect all approaches used in architectural design as shown in Figure 1, but to adopt the approach in the Figure 1's upper right corner. But here it is necessary to reemphasize the social gender perspective. For this reason, the perspective ecofeminism brings to social change also needs to be examined within the spatial context.

4. A Framework In Order To Find Out "The Way Out"

Schools of environmental philosophy discuss the continued control and pressure on man and nature using different concepts. In this respect, ecofeminism can be said to have an integrating aspect. It is said that by creating dualisms, the Western patriarchal structure shapes social structuring, the philosophy of science, and Western culture. By placing one element lower within a hierarchical system, thus marginalizing it, dualisms such as culture/nature, male/female, mind/body facilitate the exploitation of the lower element. According to the author, the elite white man's culture is above and beyond everything, and everything is shaped in accordance with his needs and objectives. Ecofeminism criticizes this approach. Underlining also the social aspects, ecofeminism argues that unless this dualist system which forms the basis of all Western science changes, an environmental transformation in the truest sense will not happen. The development concept used in the system described as the master model is itself regarded as exploitation. Exploitation happens through a relationships system that objectifies the other, places the other somewhere within the hierarchical system, homogenizes, reduces, and ignores the other [16].

Explaining the dominant design approach derived from the master model, Birkeland [20] states that in the process of design, nature is converted into an object for the sake of man's needs and aspirations. He argues that by adopting a reductionist approach the perception that man and technology are dominant to nature is being created. Thus, removing the built environment from nature, a synthetical built environment is created with the help of mechanical tools. Man is in the center, and mankind is logical, authoritative and independent. This obsession of human-centeredness, logic and authority reveals itself with an essentialist approach in the design process in the *star architect* phenomenon. Like fashion, buildings become an indicator of prestige and status.

For transformation to happen, focus should be on the development and improvement of environmental and social relations. As shown in Figure 2, within the paradigm of sustainability, design approaches that are flexible, participatory, appropriate, and locally managed can be regarded as the closest parameters to achieving the targeted goal. The approach these parameters are closest to theoretically is that of social ecologists. However, as widely stated in the literature, while Bookchin opposes hierarchy and centralization trends in society, he remains inadequate in providing a solution. The reason is that by accepting the superiority of the human mind, he normalizes mankind's domination over nature [16]. Even if design approaches developed within this context propose social equality, because at a fundamental level they are conceptualized based on male-dominated thinking, unless a solution is generated at the core of the problem, generating change will be difficult. Therefore, in order to break the structure of the master model, these design parameters should be read adopting a sexist perspective. That way, social ties can be reestablished without a hierarchical structure.

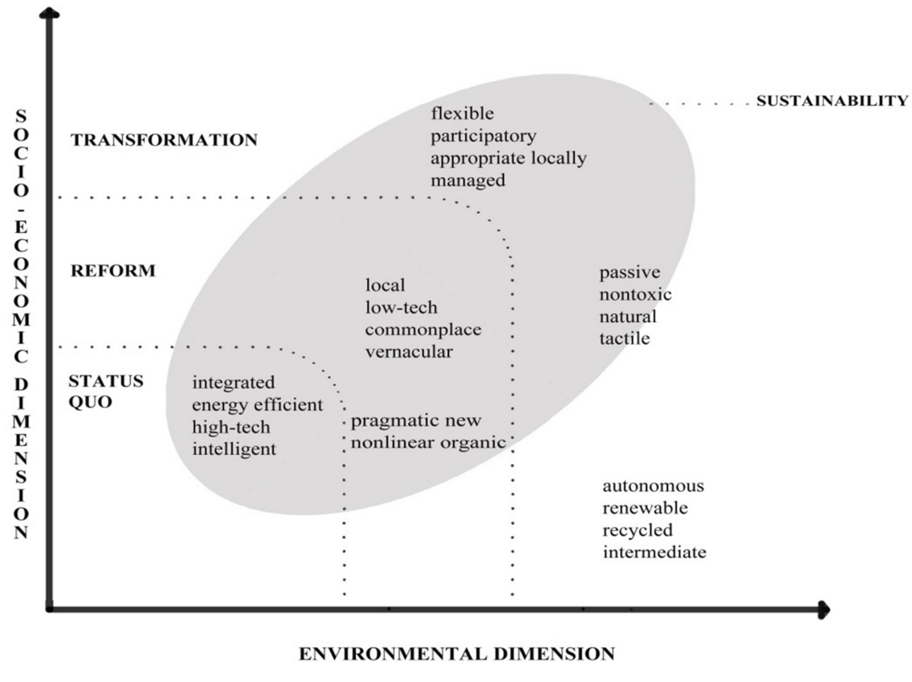

Figure 2. Positioning design approaches within the context of the proposed framework. Based on the work by Hopwood et al. [8] and Guy et al. [9].

Undoubtedly, there is a need to pursue social and ecological qualifications simultaneously while developing approaches for sustainable architecture design in response to the problems identified here. Here, adopting a holistic approach in the truest sense, and establishing a balance between the above-mentioned design parameters is important. In addition, by departing from the subject and object dualism, multiple-sensory design parameters could be considered that allow the body to sense nature and the built environment. This will allow the development of a more flexible design approach that does not make a sharp distinction between the built and natural environment relationship. At the design stage, in order to eliminate gender and class discrimination, a more organic and non-hierarchical user and social structure could be achieved through a participatory and manageable design process. In addition, with a decentralized design approach groups that have their own productivity can be created.

5. Conclusion

Impacts of design decisions may have various dimensions such as social, economic and environmental. Design choices can be the solution of a problem or part of the problem. Sustainable architecture can only be achieved with a design perspective that considers the user, society, future generations, other species, ecosystems, the bioregion and the Earth.

In this regard, the sustainability paradigm to be aspired to can be summarized as follows:

- One that is egalitarian, and advocates for a social structure with a sense of responsibility for different user groups as well as towards nature;
- evaluates local human and natural data;
- adopts a holistic perspective developed by the coming together of various professional groups;
- advocates for the efficient use of human potential, and the production of technology or materials that can be recycled in harmony with nature, do not harm human health, give back to nature what it takes from nature;
- advocates for spaces connected to nature that protect people's physical and psychological health; and
- has a concern for energy efficiency in the regional economy.

This study discussed how transformation can be achieved with the help of the sustainable design approach and environmental philosophy. The environmentalist discourse has an ideological influence on architectural approaches, as well as shaping these. However, when examining applications, the need for a paradigm shift in design becomes obvious. It has been observed that developed approaches have produced solutions predominantly for individual issues, and have been inadequate in developing a holistic approach. For transformation to occur, first of all, social transformation needs to happen. Women and nature are being marginalized through same processes and exploited. Therefore, the gender perspective's contribution to the discourse gains significance. This article is an elaboration on how this problem is reflected in design. Parameters are provided as a solution to the problem.

As the paper puts forth, in order to achieve 'real' sustainability, a paradigm shift is needed. If our current interpretation of sustainability continues, it will not be possible to overcome the defects of a crisis in the world. Thus, we have to urgently change our conceptions about nature, such as human-centrism and the control-over-nature approach. We have to talk about new ways of collaborating with nature. As known, eco-centrism represents the belief that the ecosystem has an intrinsic value and this alone is a reason to protect it, whereas anthropocentrism represents the belief that environmental protection is important because of nature's contribution to human welfare. However, based on where we are today, we argue that the eco-centric perspective alone is not sufficient. We believe that in order to achieve a paradigm shift what needs to be done first is to introduce a gender perspective to sustainability. This paper makes an effort to search for ways to discuss gender issues within the sustainability discourse of architecture.

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Technological design of urban creativity spaces: a functional classification of eco-friendly materials

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Abstract: *This contribute illustrates the results of a research work about the technological design of eco-compatible playgrounds integrated in a no quality urban square. The principle is that a smart use qualifies the space. The designer must respond to specific legal and normative requirements. The criteria of eco-friendliness, recyclability and renewability should become constraints for technological choices. While the need for the child's safety is ensured by proper design of the park, the safety of the play is determined largely by the appropriate materials choice. The research produced a classification in order to select virtuous behaviour materials, evaluating both their own characteristics and the production process. The research group developed a tool to support the decisions of the designer, which has the benefit of giving to the citizen a qualified urban space, which improves not only social relationship but also knowledge of this particularly sensible kind of user.*

Keywords: *technological design, playground, eco-friendly material, decision support system*

Methodology and phases of the research(AV)
"*We shape our built environment, but since then it shapes us*" (interpretation by W.Churchill).

According to the "Need-Performance Approach", which defines the construction quality valuating the consequence among need, requirement and performance (Norm UNI 8289:1981), a methodologically correct design must satisfy direct users' needs, meeting specific legal and normative requirements in order to select materials, components and technologies and verify the environmental, social and economical quality of their performance. Moreover, the new frontiers of development highlight the need to reduce our consumption of non-renewable resources (matter and energy) and qualify the space with transformation works producing wellness and quality of life during the use phase, but not impacting on the environment during the cradle and grave phases, on the basis of Life-Cycle Assessment methods. "One strategy for minimizing consumption in creating the built environment is improving the technological efficiency of our materials and processes". (Krigsvoll et al., 2010). Criteria of eco-friendliness, recyclability and renewability become real constraints for technical provisions for the technological performance choices according to the approach of an "Environmentally Friendly Behaviour".

The research aims at building a useful tool to the designer, who must design a playground and wants to carry out eco-technological solutions based on sustainability, without any specific knowledge about eco-friendly materials. The study was made in five phases:

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1. REQUIREMENTS: individualisation and classification of the cogent and voluntary requirements satisfied by the design

2. MATERIALS: market analysis of materials with medium-high environmental performances

3. DESIGN: 70 designers elaborated their experimental work according to the rules of the “Environmentally Friendly Construction”, only using eco-friendly materials (natural, recycled and bio-based materials)

4. USE: analysis of the design solutions and classification of the main uses

5. TOOL: three-dimensional Decision Support System, interfacing requirements, uses and materials.

As the main aim consists in having a tool easy to be consulted by designers, the main use of DSS_TOOL works from the typology of the architectural object to be carried out and not from the intrinsic characteristics of the materials more often used. Nevertheless, the choice of the material with better performances can be made just after the compliance of the architectonic elements (play, enclosure, etc.) with requirements has been checked according to law and best practices. The most important normative references are the UNI 11123:2004, UNI EN 1176:1999 (1-2-3-5-6 parts), UNI EN 1177:1999, defining the state of the art of products, processes and services; they specify “how to do the things well” and assure safe performances in terms of safety, aspect, wellness, maintenance and respect for the environment. The research methodology highlights the difference between sustainability performance of a construction and the contribution of the construction to a sustainable development. Particularly, the former is closely linked with the intrinsic qualities emerging in the phases/stages of the Life Cycle; the latter is linked with the positive self-multiplicative effects that can be produced as consequence of appropriate choices. If it is true that designing and innovating mean "to know how to choose", the mechanisms of complex development of the designing ideas must know how to answer to a question that in the meantime is evolved/renewed towards higher and higher performing standards.

Requirements of the system (AV)

In this tool, the requirements have been divided into two macro-categories: cogent (essential) and voluntary/eco-oriented (added value), because in choosing the material with better performances according to (relevant and optional) priorities, those satisfying the explicit requirements of the cogent legislative tools must be considered firstly. In the Table, the grey row represents the main requirements, while the other rows represent the optional requirements. Once the former have been satisfied, the materials showing to be able to satisfy most of the optional criteria must be chosen, so giving an added value to the design both in the cradle phase (Pre-environmental safeguard: renewable, recycled and reused raw material), and in the grave phase (Post-environmental safeguard: recyclable, reusable and disposal materials). The importance of the cradle phase is mainly linked with the principle of the "Environmentally Friendly Behaviour", according to which preventing the environmental

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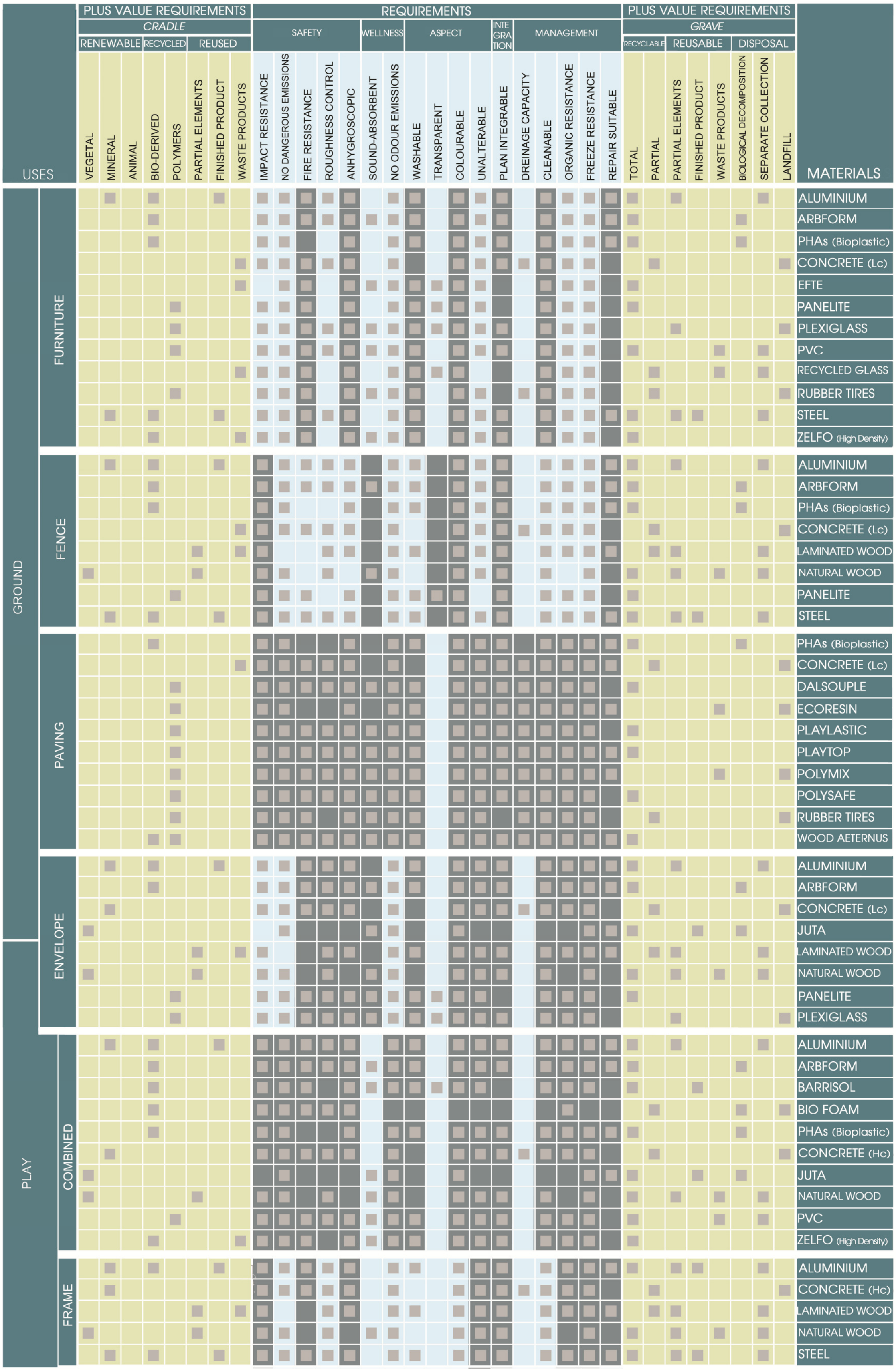

Figure 1 TOOL_ three-dimensional Decision Support System

impact is better than repairing the damage caused. It is also linked with the consideration that the materials used in playgrounds do not need to have remarkable structural performances as solicitations are limited; therefore, for example, the use of concrete with recycled materials, that reduce environmental impacts, would be desirable. Moreover, the typology of the playground involves the concept of a continuous maintenance and, as a consequence, a continuous replacement of the single components. Therefore, the grave phase deeply impacts on the whole environmental balance (matter and energy). Finally, as in the life-cycle energy consumption, the Operating Energy is low (quite zero), the reduction of the Embodied Energy has a relevant value to be managed in the cradle and grave phase.

The materials choice through the use categories of a playground (LM)
The experimental research project has developed a useful tool that works in order to support the choice of materials to be used for playgrounds. It has been created keeping in mind, as main goals, high standards of quality and safety, but also of eco-friendliness. One reading way of this decision-making tool, allows the designer to choose from a wide range of selected materials, entering in the tool from the use categories of the playgrounds elements. All use categories that characterize the establishment plays have been grouped, following the horizontal tool reading, into two main categories: "Play" and "Ground". A quality "playground", in fact, is not only a set of playful equipments placed anywhere, but also it is a space where every detail is designed: urban furniture, paths, fences and play equipments. The analyzed projects are composed of elements that are not always linked to the usual play equipments (swings, carousel, slides, bouncy castles, climbing structures, elastic plays). Therefore, they can be defined as a *new play*.

The technological and functional classification of the new play's elements arises from a careful reading of workshop products. This elements are “Frame” (the structures of play), “Envelope” and “Combined” (related to plays where is not possible to distinguish structure and envelope). For this category, of which the project "The Stain" is an example, the Zelfo turns out to be a high performance material. In fact, it satisfies most of the priority requirements for this use category. In addition, it is a good-looking material, but especially it is a low environmental impact material, both input and output in the production process.

Particularly, “Envelope” is the skin, which is what confers the shape and the external finish to the play elements. As a result from the analysis of the workshop designs, it is not possible consider separately the play's envelope and the playground's remaining parts. It can become a path, a covering or border element; it can turn even in an urban furniture or a paving piece. Therefore, "envelope" is placed in between the categories "Play" and "Ground".

The "Ground" category includes everything that is not a play, but that it is essential for the creation of a playground that we can define of quality. This main category is also divided into other use sub-categories: “Paving”, “Fence” and “Furniture”.

“Paving”_ The EN1177 specifies in particular what are the requirements: for surface coatings to use in children's play areas, and for surfaces needed to cushion the impact. The paving

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choice depends on the most suitable equipment and their heights of fall, as established by law; but also by wear resistance and stresses, and variable characteristics in time. Compared to artificial paving, natural ones require, for example, more maintenance, but if used, reduce certainly the environmental impact. Therefore, the appointed designer must operate significantly the more tailored choices to the required needs.

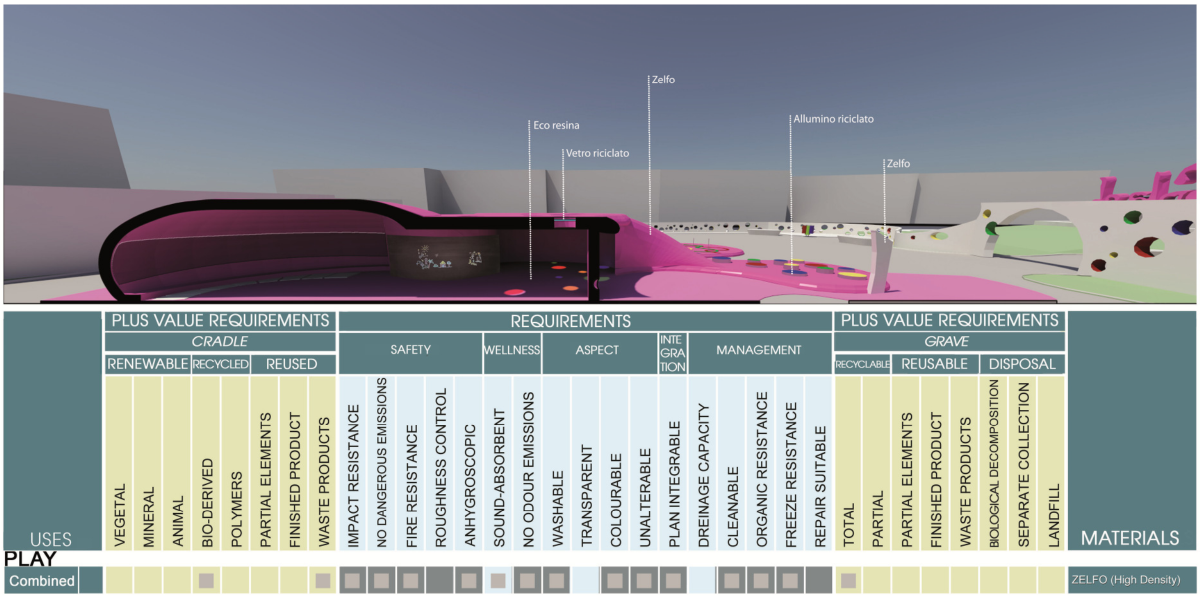

Figure 2: Zoom on Tool_ Zelfo: eco-friendly material for combined play. Plauground Design: "The Stain" (Amatucci A. F., Esposito A. and Battaglia M. Designers)

"Fence"_ even the fence plays a key role in the creation of a safe and high quality play area. It is not only a border and protection element of the area from the street, but thanks to appropriate architectural solutions and smart materials choices, it can become a device capable of reducing noise pollution. In addition, it can provide a means of social and art communication, and therefore an attraction element.

"Furniture"_ the materials choice for the urban furniture in an educational and quality playground, does not deserve less attention. This type of playground should be designed in accordance with the needs of the main users, the children, but it also has to be designed keeping in mind the needs of other types of users: the grandparents or parents who accompany children for example. Moreover, a playground can also be a meeting place for teenagers. In this context, it is also important to properly design the furniture, which can be seating, shading devices, totems or decorative elements.

An eco-friendly materials classification (FV)

The playgrounds' materials choice mainly determines the safety of child in the way of the safety of playground is ensured by a correct project of the park. The choice of materials, in a playground design realization, is essential, in terms of legally binding requirements, to guarantee both the quality of immediate use, and the long-term performance of each part. The materials, according to the tool, are selected according to the prevailing application in current practices of playgrounds design, and in particular for this experimental methodological application are considered in eco-friendly reading.

The classification of eco-friendly materials follows the Life Cycle Assessment principle, therefore introducing value-added requirements aimed at safeguarding the environment impact of materials according to the origin "pre-environmental safeguard requirement", the operating phase, until the disposal "post-environmental safeguard requirements". Therefore, the materials are collected depending on their origin "the cradle" in three categories renewable, recycled and reused materials.

The "renewable" materials are those from vegetal, mineral or animal sources, these are capable to regenerate themselves in nature; as well, they are mostly indicated for the low impact on raw sources, but they need several processes to ensure the child safety.

The "recycled" materials are those from a previous use disposal and they are mainly from bio derived or polymers pulverization treatments: these processes modify the performance, especially in resistance, of original source because of elements mixture.

The "reused" materials are, instead of recycled ones, those derived from a removal. This category includes the materials derived from waste products (both powders and scraps), the partial elements and the finished products; naturally, these are medium adaptability materials, especially the finished ones, because the previous use can affects dimension and integrability.

The workshop results point out a large type of finished products in the playground (e.g. tires, pallets, reels or PET bottles), these elements although economic, eco-friendly and very common, cannot be introduced in a material classification. The "post- environmental safeguard requirements" introduce the concept of material disposal, after them use in different playground elements. The "grave" of selected materials identifies three categories too, the recyclable, the reusable and the disposal materials. The first category considers the possible recycling process of materials, in fact includes the partially and completely recyclable materials. These different definitions are aimed at evaluate the variables of materials during their life applications, until preventing the capability of materials recycling, because they modify the inner material proprieties.

The "reusable" materials are those re-introduced on the production processes as partial elements, finished or waste products. The installation phase of a material, in fact, can modify permanently the materials' characteristics and sometimes determines the only reuse of the finished product in itself. The latest grave category is the "disposal" of material, in separate collection, if it is possible, otherwise the landfill storage where is necessary. Naturally, the landfill storage is the worst solution in terms of material footprint on environment, and it is the possible option for each of these materials; but for this experimental application, is indicated in all the cases where the disposal is cost-efficiency trade-off more favourable. The materials selected are a data collection from the research experimentation so they are obviously limited and simplified in order to intercept the appropriate use for a child

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playground and respect the operational requirements through the tool. For this reason, some of materials chosen for the research are proprieties specified, such as the concrete that is the most versatile of material selected because it is appropriate for every application. If it is a low resistance class is for ground use categories and if it is a high resistance class is for frame and combined use categories. As we can read in the tool, the natural sources materials achieve best performances in the L.C.A. evaluation, reducing the impact on raw sources, because they are mainly derived from renewable material and furthermore they can be re-introduced in different output on production processes. However, the renewable materials are low adaptable to different kind of uses, because they cannot guarantee optimal performance in operating requirements without some focused interventions. For instance, the natural wood (no coloured and treated) is more efficient as frame or fence because it guarantees, for its own proprieties, good safety, wellness and management performance, but is low convertible to other use due to its low performance in aspect requirements. Otherwise the polymers derived materials constitute a large market slice, especially because most of them are appropriately realized for the playground application (e.g. for the paving surfaces). In this way, these materials guarantee high operating performances in all requirements classes. Moreover, the polymers derived materials can achieve good performances in terms of environmental safeguard requirements: a large part of them in fact is recycled and recyclable, seemingly never-ending, to constitute the same original product with the same performances.

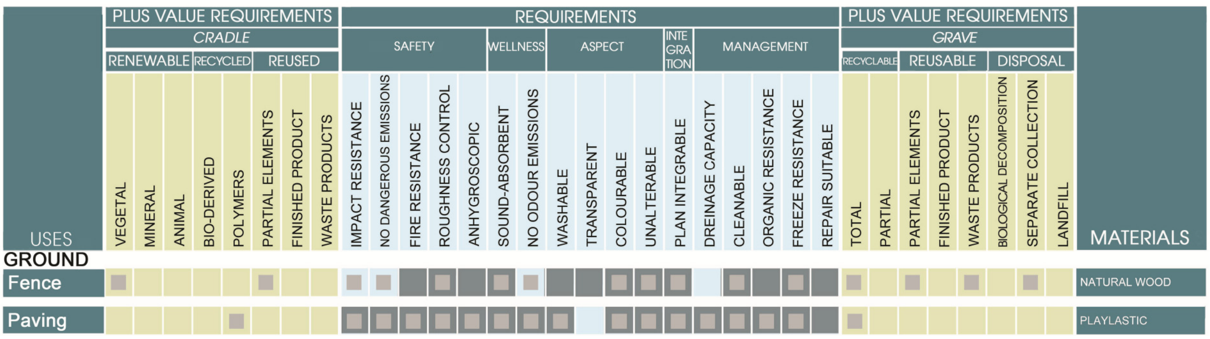

Figure 3. Zoom on Tool_ natural wood and Tool_playlastic: eco-friendly materials for fence and paving

Conclusion (AV)

The research design is still in progress and its experimentation aims finally at building a dynamic and implementation-suitable database having the added value to be a useful and easy tool supporting the technological design.

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Better Water Governance for sustainable development: A Case Study of the Chi River Basin, North East Thailand.

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Abstract: *This paper addresses a water governance study that examines the main agencies of water resource management from macro to local level, and various views from the actors and villagers in the river basins in Thailand. At macro level, the fragmented of relevant ministries of water issue and the coordination of different political parties are the major problem of IWRM. For area-based implementation, the articulation between the different departments of water issue and local authority is the crucial gap since there is no organization is able to plan and manage all issue about water resource management across the river basins. At local level, deterritorialization and deregulation of local authority to plan and manage water resource are require for IWRM around the river basins since local authority has limited role, budget and area for local development. Hence, this study therefore proposes that cooperation (sahakān) is the primary concern for local authorities as the formal actors at local level to manage water resources among rural areas or else communities based on the same river basin.*
Keywords: Integrated Water Resource Management (IWRM), Water Governance, and Chi River basin

In Thailand, there is conflict regarding water usage from the dichotomy between national policies *versus* local practices which results in ineffective irrigation systems. As well, the multiple functions of irrigationsystems, and the relationships between different levels of management and as a consequence, they fail. Remarkably, the crucial gap of local authority is to focus on administrative areas rather than the coordination across the administrative areas. Therefore, water resource management has not been fully included in the responsibilities of local authorities since it requires the cooperative planning and implementation beyond the limited areas and budget of local authority.
The IWRM is considered worldwide as a means to reduce social conflicts from competing water needs among the stakeholders from both government and local participants. IWRM process therefore offers an opportunity for agencies, water users, local communities, and other stakeholders to share basic knowledge on water resources and constraint in a river basin as well as to express their views and/or concerns so that agreement could be reached on way to move forward.

Integrated Water Resources Management (IWRM) is defined by the Global Water Partnership (GWP) as follows:

> "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems."[1]

However, Biswas (2008) interestingly argues:

> "This definition, on a first reading, appears broad, all-encompassing and, perhaps even impressive, at least linguistically. However, such lofty phrases, when scrutinized carefully and objectively, have little practical resonance on the present, or on future water management practices" (Biswas 2008, p.8).

The notices from Biswas are useful for the planners to scrutinize before adopting IWRM at both institutional and local level. In Thailand, IWRM has been technically recognized as a means to achieve sustainable water resources management and the concept has been incorporated in the national policy for more than 15 years (Apichart 2011, p.3). However, clear institutional responsibility and introduction of the IWRM concept to local communities are relatively new.[2] In theory, the IWRM approach promotes the concept of government as a facilitator and regulator, rather than an implementer. In practice, the formal actors from the government sectors who hold full authority of water issues have not paid enough attention to adopt the ideas from many River Basin Organizations (RBO) and developed water resource management as a whole system. Therefore, RBOs are not able to transfer their ideas to tangible achievement of IWRM.

Power issue, role of agencies, and IWRM

In Thailand, there is the dichotomy between centralization and decentralization approach in dealing with water issues. The structure of bureaucratic system is still the crucial obstruction in solving the problem of water management in Thailand. At macro level, the power of consideration the projects and budget is based on the centralization via the MAC. However, the MONRE has less priority of subdivision budget to tackle with water issue in urban areas. This problem is still in the grey area which has not been solved from the politicians who have power of making decision. At local level, the Governor believes that the CEO (Chief Executive Officer) system might do better for cooperation between the provinces or even the regional since CEO governors in the river basin would be able to operate the fragmented budget and responsibilities in their provinces for better efficiency.

However, this idea reflects the idea of deconcentration which is hard to prove the result since this may be the centralised power to MOI later rather than to encourage local authority and

[2] In 2005, the Department of Water Resources (DWR) of the Ministry of Natural Resource and Environment (MONRE) have been assigned to take the lead in forging effective IWRM implementation and 25 river basin committees (RBCs) have been established (World Bank 2011).

local people to plan and manage their local resource. In theory, Ministry of Interior (MOI) has created cooperation (*sahakān*) between different local authorities, such as between Tambon Authority Organizations (TAOs), and between TAOs and Provincial Authority Organizations (PAOs). In practice, it is hard to see the evidence of this in the local authorities' management of their resources because of the amount of bureaucracy involved. In particular, there are no guidelines for establishing a formal inter-local association for joint service delivery (Pechladda 2013). For instance, Provincial Authority Organization (PAO) has not taken part in water resource management around Chi River basin in the Northeast. PAO only serves the road construction and digs the small and medium ponds in rural areas. Therefore, the crucial missing link is that the provincial hall, PAO, municipality, and the villagers have no role for managing river basins.

It is argued that an inefficient centralised bureaucracy together with inappropriate local administration remain the greatest barriers to the success of local development in rural Northeast Thailand (Baker and Pasuk 2005; McCargo 2002, pp.50-60; Parnwell 2005, p.4). Although reforms introduced in the 1990s, such as the creation of local authority, have provided some degree of decentralization, they have not created genuine local self-government (Nagai et al. 2004, p.4; Arghiros 2002, p.229). To address the challenges on water resource management in Thailand, and commitment of the key agencies and policy makers and effective cooperation of the water users will be necessary. The most important factor is the implementation of IWRM. The case studies of the river basins in the Northeast illustrated the discrepancies in the roles and powers of politicians at both the national and local levels, with local organizations – as the key formal actors in local policy-making – not having enough power (Molle 2005). While the agencies of water issue in government sector are scattered in various departments, the head of sub-districts and the governors are the center of power, news, and help in district and provincial level. Those two actors are not involved with water issue, directly. They however are able to relief the sufferings of the villagers in a short term.

Irrigation system requires a large enough budget to secure the continuity and the stability of water resource management in responsibilities. The weakness in local policy-making in three selected villages thus results from the lack of a powerful response by local authorities and other departments related to water issues. Local authority lacks the power and capacity to deal with irrigation problems, as irrigation and spatial planning requiring coordination between various agencies or cooperation (*sahakān*) at the network level. However, irrigation is the largest scale developmental problem which requires a syndicate of neighbourhood areas, PAOs and institutional actors to deal with it. By itself, this local authority can only deal with the surface problems of public works in their administrative area. In theory, cooperation among local authorities provides an effective solution to these challenges, but such syndicates of inter-local cooperation (*sahakān*) are not clear for implementation by the bureaucratic system. In practice, "first, a local authority is prohibited from using its budget funds outside its territory as a matter of principle. Second, there are no guidelines for establishing a formal inter-local association for joint service delivery or cooperation (*sahakān*). Third, there are legal problems" (JICA 2007, p.23).

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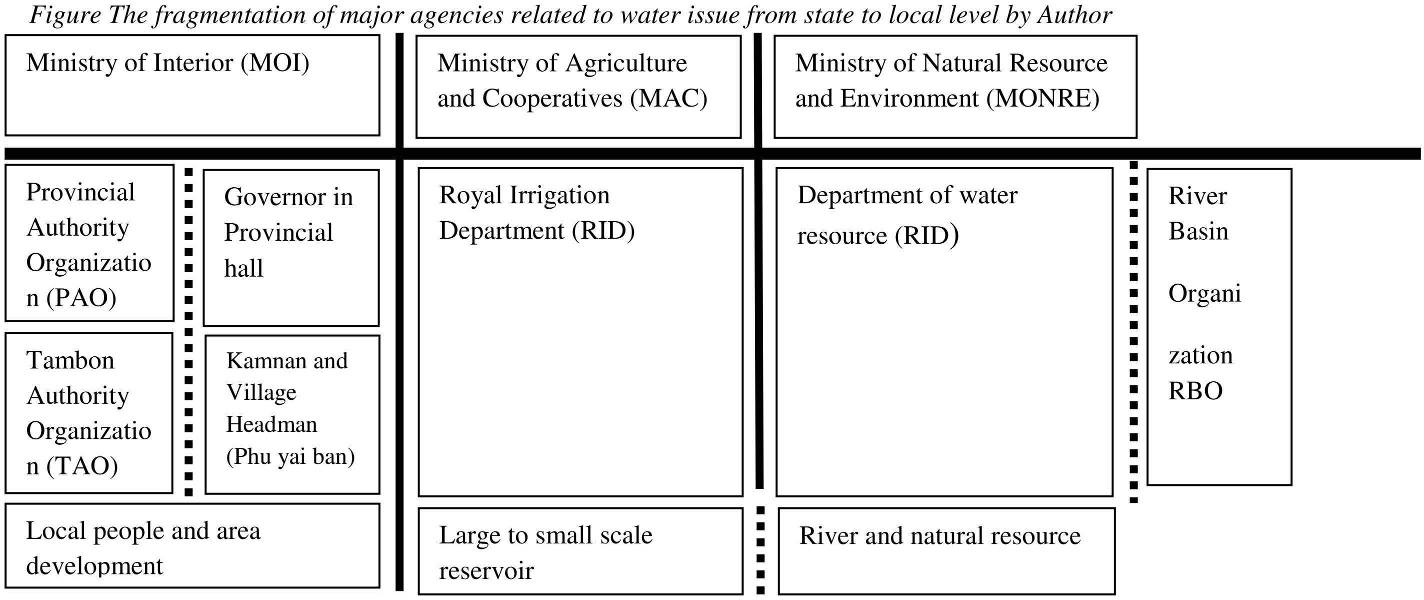
Importantly, this paper argues that fixed boundary and rigid pattern of administrative areas of the existing context of local authority is not able to tackle with water issue in this day. This study therefore considers that cooperation (*sahakān*) is the primary concern for local authorities as the formal actors at local level to manage water resources among rural areas or else communities based on the same river basin. At this moment, the examples on concrete practical IWRM in watershed are still rare to upscale to the changes in structures and broader policy level. As argued, at macro level, MOI, Ministry of Agriculture and Cooperatives (MAC), and Ministry of Natural Resources and Environment (MONRE), have been assigned to cover work in relation to water resources management. Royal Irrigation Development (RID) under MAC is the major department for the provision of irrigated water for agriculture, Department of Water Resources (DWR) under MONRE is the core agency in the formulation of policy and integrated water resources management plan in the river basin system. In dealing with floods and droughts, many government agencies have settled up centers or task forces to specifically address these issues. DWR has established a Water Crisis Prevention Center and installed a number of gauges in priority river basins, including an early - warning system in some of vulnerable areas. RID has also improved its capacity to predict the water flow and improved efficiency of its reservoir operations.

There are some discrepancies from these sectors at macro level and it also needs to be solved through coordination both policy and budget from integrated view from the key persons of these ministries from politicians to officers in government agencies who are in the high positions and have power. In terms of planning practice, the municipality often follows the rules and responsibilities of state policies rather than tackle with water resource management as discussed. At local level, to strengthen the capacities and cooperation between local authority and local people is also important. Therefore, the local people and agencies involved should cooperate through providing and sharing of information, knowledge, and funds since they can tackle the problems, and can effectively manage the conflicts.

Figure The fragmentation of major agencies related to water issue from state to local level by Author



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As illustrated above, the fragmented bureaucratic structure between the main agencies between MOI, MAC, and MONREat state level is the most crucial obstruction which should be reformed for better cooperation. The government only focuses on the water management in 2 levels. The first level is irrigation in a large scale such as to create dam and reservoir. The second level is to dig the individual pond at household level. Hence, the cooperation between macro level and micro level through local authority, Provincial Authority Organization, and local authority such as Tambon Authority Organization is required for area-based implementation.

To deterritorialize administrative areas in local level for the transboundary of water resource management, this has affected the responsibilities of TAOs since the responsibility of TAO is only in administrative area. While water issue cannot be fixed in exact area, each TAO got stuck in the same trap of problems since they cannot share budget and resource for the cooperation of water resource management. Additionally, TAOs have not thought beyond the government framework for either routine work under the hierarchical administration or for physical development, choosing to simply follow the municipality model of towns (Pechladda 2013). Hence, this paper considers that deterritorrilization is the solution form managerial area of water resource management for the river basins in Thailand. For example, to empower local authority, Provincial Authority Organization (PAO) and Tambon Authority Organization(TAO), for managing water resources in local areas. PAO should take to the role of facilitator to provide knowledge, budget, and project of water resource management in provincial area and local areas through the coordination between provincial hall, RID, DWR and TAOs.

Conclusion

At macro level, the cooperation between the relevant ministries of water resource management is required both reform of bureaucratic structures between MOI, MAC, and MONRE. Additionally, the coordination from different political parties is also needed for IWRM both macro and local level. The articulation between macro and local level is the crucial of gap of water resource management for area-based implementation since there is no local organization takes the responsibility for water resource management across the areas around Chi River basin, continually. The river branches in Chi River basin are crucial for water retention and environment. These largely complicated problems have not been solved by local authorities such as the Tambon municipality. Hence, to introduce long term planning of the efficient resources, water and land use is important. As discussed, water resource management in both urban and rural area should be planned together as a comprehensive plan to see the causes and effects among each other. Feasibility studies could be undertaken to assess the possibility of sharing information, irrigation systems, and resources for clustered areas of local authoritiess – so called cooperation (*sahakān*).The legal aspect as comprehensive plan of the department of Town and Country Planning for sustainable land use planning should be integrated as full implementation at local level through the enforcement of macro level. Hence, both IWRM and cooperation (*sahakān*) need to challenge the conditional

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problems from the bureaucratic system, including deregulation, bureaucratization, and deterritorialization.

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Urban planning in the Non-City. New tools for an active participation in a process to plan the growth of irregular settlements in Andalusia

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Abstract: *Within the Project I+D+I "Urban planning in the No-City", awarded after a public tender by the Public Work Agency in Andalusia. The case study of the irregular settlements, which exist in undeveloped land in Andalusia, is presented having as a main goal to define management strategies for its urban-territorial integration.*

For that purpose, a combination of Geographic Information Systems and models of urban simulation done by multi-agents will be used, basing on the software application Netlogo. This tool will help implement the tasks relying of spatial planning with a process of online public participation, which would contribute to the balance between the potential solutions and the socio-economic reality of the framework under research.[*]

Irregular settlement, Non-City, Urban Modeling, Spatial Planning, Participation.

Introduction

There are around 350 000 illegal constructions in Andalusia in undeveloped land, which highlight a strong land, urban and social problem, and which nowadays constitute the biggest mortgage to achieve a rational, coherent and sensible land order in most parts of the Andalusia land. Despite the fact that within the flourishment of these type of settlements concur several nuances, all of them share some similar characteristic features: its spontaneous character and lack of planning, the environmental affections they provoke or a generalised lack in their facilities and infraestructes.

Until now, the solutions which have been so far devised from the Administration reveal its incapability to solve in an efficient way these problems and, to a certain extent, they show a

[*] The autors would like to thank the FEDER of European Union for financial support via project *El Urbanismo de la No Ciudad* of the "Programa Operativo FEDER de Andalucía 2007-2013". We also thank all Agency of Public Works of Andalusia Regional Government staff and researches for their dedication and professionalism.

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progressive blank space between the normative-regulative frame and reality, which is to be reordered. Therefore, in an unilateral way, these differential processes of a model of compact traditional city are tried to be assimilated. This fact is producing major distortions, insolvable solutions or unviable ones, which cannot lately be practised.

On the other hand, if there is something, which can be learnt from this process of illegal invasion of the undeveloped land, is that, when the residential settlement acquires a considerable scale and dimension, the only acceptable -political and social- solution consists of its urban acknowledgement. This implies the granting of an adequate classification of the land, as well as the implementation of the given measures in an infrastructural and dotational point, which grant a minimum qualification, which will lately ensure the reversion of the lacking congenital symptoms, which go together with these kind of settlements.

Consequently, the demand for a new focus or perspective from which the problem can be perceived is a must. It attends in a good part to the specific features of these alegal processes, and plan innovative alternatives in which an active participation of the citizens is vital.

In these irregular lands, carrying the citizen's demands by an efficient participation process, which guides decision-taking processes, turns out to be essential nowadays. Therefore, a new way to deal with this problem is proposed, basing on two basic pillars: the use of new information technologies (NICTs) and an effective citizen participation, by means of an online tooling process which allow us to generate a truthful diagnose and in real time, at the same time that the formulation of interactive intervention alternatives operate (1).

The basic features, which are really operating in these irregular settlements in Andalusia, can be summarised in the following points:

The infrastructural component, which comprises basic supply needs and wastewater treatment coverage, electric energy and light, and collecting solid waste are the main points which constitute the chief and common troubles widely in almost all irregular settlements, since it affects directly to the environment. The irregular occupation of a natural land within which all the anthropic actions of urban condition act produces a land transformation, which damages its original attributes.

The second thematic area constitutes the normative and socio-economic context, where it is generally more important the deregularization of these aspects and the difficulty to give a solution. The attempts done up to now, using common urban tools, are very difficult to realise and derive most of the times in an stagnation. This context, which is nowadays more remarked due to the crisis and economic crash, generates a growing distance between the administration and the social reality of these two ambits. A frustrated planning or its absence is its main consequences, just because of the use of the inadequate tools for an effective viability of solutions.

Apart from these two main thematic areas, Andalusia irregular settlements have a common feature: the problem of mobility and the absence of services and dotations. Despite their condition of basic needs, the problem, which stems from mobility in these areas is a consequence of the remarkable difficulties to have access to services and nearby dotations, as well as the daily travels for job reasons. All that generate unsustainable models, which are able to subvert urban and land planning, at the same time that they reveal the deficient hypotheses, which undergo planned sceneries.

Application of New Tools to participation processes

The link between the two basic pillars is going to be introduced in this paper: new information technologies which are able to generate new analysis, diagnose and intervention tools to deal with complex problems; and citizen participation, understood as an enriching planning process.

New urban tools provide a technological revolution in contrast to the classical forms of planning, and they try to adapt to the new demands of the citizens. In addition to this, they generate new platforms in which the urban complexity of our times can be dealt, where dynamism is a determining factor. The scientific method applied to planning is equivalent to the quantification and qualification objectivity of urban and social reality of our lands. For this purpose, the implementation of GIS tools linked to an urban simulation seems to be an ideal urban-land diagnosis and experimentation framework.

Georreferenciation means to have a land knowledge, placing the reality of the database associated to space, understanding that problems are measured and defined in an specific way. This way, it helps us place problems in its context and depth. Once known and placed the context of the problem, there are two ways to follow: prolong the current trends, or otherwise, introducing punctual or integral changes and have a look at possible new tendencies. All of that, using tools of urban simulation. There is a question, which we must wonder, which the sense of urban simulation is, as an experimentation methodology applied to urban planning. This way, M.Batty states: “Models are simplifications of reality – theoretical abstractions that represent Systems in such a way that Essentials features crucial to the theory and its application are identified and highlighted.” (2)

Urban simulation, in our case, done by means of multi-agent systems, is based on finding determining factors of the behaviour of the case study; extracting out, therefore, the patterns or tendencies by means of a starting-point situation. In a specific way, the software application Netlogo will be used, thanks to its versatility with respect to programming and visibility. Thus, it is adequate to the needs of experimentation of the cases of study.

The need to use computer-based tools stems from the complexity of the problem, which is to be studied; thus, urban simulation is now a trend since it operates generating new ways of attending planning problems as well as urban management problems. Parts, which generate the whole complex; compose the city, either the orthodox city as the irregular one, and all these autonomous parts are working as independent variables.

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As M.Batty asserts: “Urban models are thus essentially computer simulations of the way cities function which translate theory into a form that is testable and applicable without experimentation on the real thing. […] Computers act as the laboratory for experimentation on phenomena which is represented digitally, with its manipulation being virtual.”(3). As David Maddox pointed out even more recently, “ the participation exercises which simulation models use as tools -work- so that people do not only talk about their opinions, but also about the consequences of their opinions” (4)

Case study: Methodology and tools

In order to introduce a pragmatic sense and its application to the cases of study, the methodology and process will be explained one after the other. Thereby, these new tools will be explained, which are a fundamental base of a different way to make processes of citizen participation, which are adequate to the process of ordering, management, and execution of Andalusia irregular settlements.

The case- study from which we depart has the characteristic features of the problems, which concerns us. It marks the scale where we can implement these new technologies. The area to study contains all the already explained thematic areas, and it is settled in the coast, having its major use associated to second residences and having a high degree of tourist occupation.

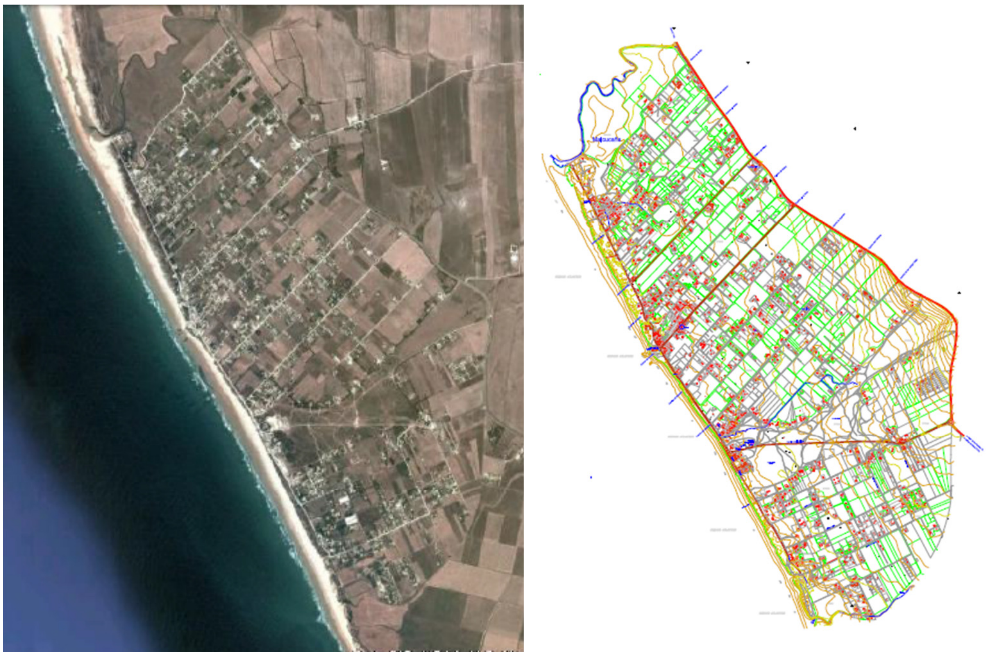

Figure 1. Orthophoto and mapping of El Palmar (Vejer de la Frontera, Cádiz)

Regarding facilities and infrastructures, water supply is done by means of pits and sanitation services, by means of a septic tank in most of the cases. This way of managing the water cycle is very common in an urban environment, where there are no problems due to its isolated character; however, when the settlement starts to be more crowded, and to have a higher density, the environmental damage can reach alarming levels. The environmental impact of these type of settlements is relevant nowadays as well as the absence of basic facilities and infrastructures, which is producing a land-urban model full of incoherencies, waste and chaos; thereby, it is impossible to attend the needs of the infrastructures and environmental

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preservation without adjusting the irregular settlement within the physical-social reality of the surroundings.

The normative and social context is part of the most difficult parameter, which has to be introduced within the new tools. This difficulty comes from the variety of available situations, density in non-lineal processes regarding land-occupation, which give as a result a problem with a lot of differences. Apart from being irregular, most of these settlements suffer from severe sectorial affections, derived from its proximity to protected areas such as: public coastal domain, public land domain, public hydraulic domain, flooding areas, etc. All that, plus a diverse social reality, which moves from the first residence of settlers of all economic levels, to the occupation of a second residence which is clearly associated to tourist spaces, which generates a greater difficulty regarding the distribution of responsibilities and costs which come together with the regularization process.

In this sense, a so complex thematic area as the normative-social one contains all the variables, which must be introduced in an urban simulation model. Therefore, the most determining elements for a rigorous participation process should be known. Given the case that there is not information available, certain patterns of social behaviour will be observed. N orders that these lacks do not suppose a decrease in the rigour of the work production; information programming will be assimilated to these social components in the buildings. That is to say, attributes of the citizens, to the simulation extent, are incorporated to the building so that to solve potential lacks.

Dotations, services and mobility are aspects, which suppose an immediate consequence of the former problems. A place settled far from the urban core, couldn’t be self-supplied regarding employment, services and dotations.

This circumstance comprises the presence of dotations in the irregular settlements, which in general, are absent, at the same time; some of these dotations and infrastructures get collapsed in the nearby nucleus. Nearby services usually correspond to these two types: tourist ones and local ones; sometime the tourist ones supply local ones, therefore the settlements lack nearby basic services. So, the needs that are searched in proximity, generating overcharges of mobility, which were not contemplated in the planning of the communication system.

All these thematic areas could be dealt in an individual way. Studying, analysing and diagnosing specific problems of each thematic area would be a long process in which sectorial solutions will be found; however, what we are looking for are integral solutions and which interact at the same time with the rest of the thematic aspects. Thereby, first a field of study is defined, able to be a GIS object with an associated database. Later, a simulation model of the initial state is designed, so that the determining factors can be understood. Finally, by means of a participation process, the determining phases of the simulation, which help us in a better way as a planning tool, are worked in each phase

To obtain the original information, an online participation process is done, which implies a streamlining of it. Moreover, the fieldwork done before is complemented. This process means changing radically the way of understanding the relationship technician-citizen, implementing a mutual learning space, which provides with visibility the citizen with the planning and the other way round. This way, these tools would widen its reach regarding inner tasks of scientific experimentation and confronting with the urban-social reality, fostering active and

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dynamic processes, which are made by means of instruments in the future generation of the city. In our case, it could be an efficient tool to get a balance between the proposed solutions to the irregular settlements and the costs of their regularization.

To find the balance, within the framework of the research project, the concept of optimal density is abstracted. Traditionally, the density in urban terms, was the number of houses per hectare. Today, the parameter that best defines the density would be the buildability (m^2t/m^2s) In the field of computer programming, has been taken that the density may be optimal if we find a balance between three concepts which arise from the subject areas previously commented: environmental impact, social impact and economic impact.

If the three impacts are capable of generating balanced trends, we could say that the density is optimal. The importance of this concept is that it becomes a tool with double utility: to the planner, that he can experience a more coherent form of urban growth, and to the user, being able to understand the significance and consequence of his opinions on the territory applied.

The model is formed by the main interaction: A "slider" value associated with the initial density model. In this context, we can intuit, before the results, circumstances that may occur according to the analyzed behaviour patterns in the area.

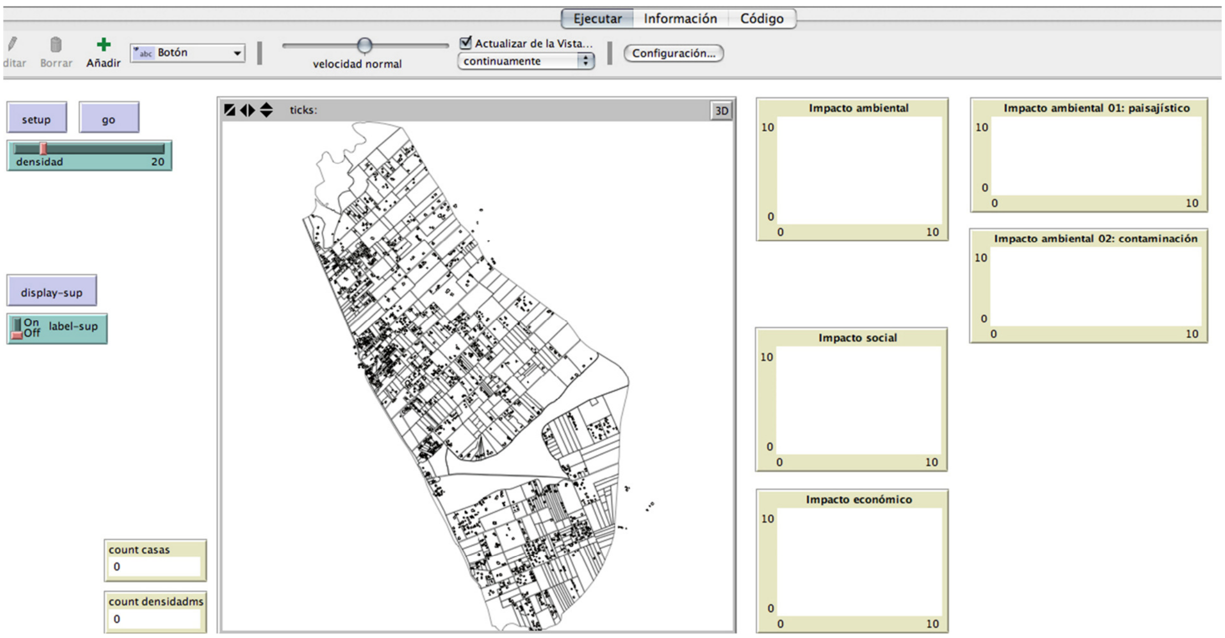

Figure 2. Urban model El Palmar - optimum density (Vejer de la Frontera, Cádiz). In development. (5)

If the area is not urbanized (having endowments, infrastructure and services), find an area that continues current trends. The environmental impact has growing trends, and the impact of pollution grows exponentially. The landscape impact is low at first, but due to long-term damage caused by pollution, eventually also have the increasing trend; so that the environmental impact would be negative. The social impact may be low, but long-term, due to the interplay of environmental, have negative trends. The economic impact is a big question; the reality is that the area does not contain changes regularization, so the economic impact would be based on patterns of residence compared to urban land use section is concerned and would remain stable.

However, if we introduce changes to the model, several cases can occur: a high-density lead introduces a radical change in the impact on landscape, including architectural styles that would modify the identity and the current landscape of the area. Consequently, the environmental impact would be increased, adding to social and would no longer be an area of high landscape and natural value. On the contrary, the economic impact would be very low due to increases in urban use that may materialize. The social impact, based on the resident population in place, would be negative, since the demands of citizens that are required today is based on basic needs, not reaching changes in the area occupation model.

In contrast, if the density takes mean values, the model would be more efficient in the definition of the optimal parameter. It is reasonable to think that the middle parameter is right, but this research stems from the need to experiment with low or medium density, and even combining densities to achieve optimal density that balances the three impacts.

In short, both the three impacts (environmental, social and economic) as density as object of interaction would be a prospective tool of a complex area, which the Orthodox's solutions are not viable.

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Session 121:

What conditions must models and methods fulfill on an urban scale to promote sustainability in buildings ?

Chairperson:

de Santiago, Eduardo

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

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Mitigation of the energy-water collision through integrated rooftop solar and water harvesting and use for cooling

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Abstract: *Conservation policy is usually developed for regions that encompass only one environmental realm because of logistical, institutional and political constraints. This is inadequate because these realms often interact through processes that form, utilize and maintain interfaces or connections, which are essential for the persistence of some species and ecosystem functions. I present a conceptual framework for sustainable development that explicitly accounts for energy and water demand of the built environment offset by rooftop harvest opportunities. I wish to challenge you to think of PV solar and rainwater that can be captured on a roof and used in evaporative coolers and water-cooled vapour-compression air-conditioning as a substitute for water and electricity that would otherwise be drawn from networks. Rainwater cisterns are often overflowing without the recognition that they are full of refrigerant R718, containing 2.37 kW-hours of "coolth" per US Gallon which can be applied to improve the energy-efficiency of air-conditioning systems, and to mitigate urban heat islands by supporting vegetation and water-features. To this end I have developed a rainwater harvesting wizard http://gettanked.org/ coupled to estimate demand for irrigation, swimming pools and evaporative coolers. I am contemplating adding a complementary rooftop solar PV system sizing tool for climates where monsoonal conditions require vapour-compression dehumidification. In the process I have been assisting in the informing Australian and New Zealand households of the relative efficiency of heat and cooling appliances that have emerged on the market. So I have prepared design data for 69 Australian and 18 New Zealand locations in collaboration with New Zealand's National Institute of Water and Atmospheric Research (NIWA) in updates of the climate data files used in Australian and New Zealand house energy rating schemes (HERS). Design data are normally distilled from meteorological records to represent design conditions that are exceeded only rarely, but can also be derived from representative meteorological year (TMY) files provided at the EnergyPlus website. ASHRAE's (2013) analysis of World Meteorological Office database also informs the limits of evaporative cooling effectiveness, but the TMY files are essential to obtain bins of coincident parameters that measure the frosting of heatpumps. The design data are temperature, humidity and solar radiation coincident with extreme events. Design data are required for calculation of peak thermal demand of the built environment. These data are essential to the design of heating, ventilation and air-conditioning (HVAC) systems and will be posted at http://suntank.org/ as they are developed.*

Keywords: Rainwater Harvesting System; Evaporative Cooling

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Why the world needs rainwater for cooling buildings

Coolth is a mass noun of the English language that indicates a pleasantly low temperature, a status that is the driver behind the air-conditioning industry (Prins 1992). The market to deliver coolth in the built environment can be to partially served by rooftop harvested rainwater, similar to the intermitant supply of electricity by rooftop solar panels.

The creation of coolth indoors while it is hot outdoors is analous to the creation of warmth indoors while it is cold outdoors. The demand to deliver a perception of warmth and coolth is less critical than the duty of refrigeration in food stores. Refrigeration is measured by the "ton" capacity (12,000 Btu/hr or 3.51 kW), reflecting the deep cooling effect of constantly melting 2,200 pounds of ice each day, sourced by an international industry (Blain 2006). The use of refrigeration capacity "tons" may be misguided in the coolth market, and so the US Gallon of liquid water is proposed as a measure in keeping with the imperial units. Willis Carrier (1911) developed an industry founded on maintaining coolth throughout the built environment – without regard to passive design principles. Air-conditioning, being defined by the shear well served by water.

Rainwater harvested from a roof and stored for use in evapotranspiration demands of green roofs, living walls, urban agriculture, and firefighting depends on the 2.26 MJ embodied coolth per litre of water as it transitions from liquid to vapour. So let us value the coolth of rainwater harvested, stored, and used in all manor of evaporative cooling processes.

The coolth of liquid water has also been essential to the baseload thermal power industry that has here-to-for provided 90% of electricity generation (Wiser 2000). Coal fired thermal power systems typically consume over ½ US gallon per kWh electricity generation (Meldrum et al 2013), while nuclear and concentrating solar demand substantially more water per generated kWh. Since the electrity demand of air-conditioning is typically 1:3 (seasonal average of 3 COP), the indirect water use of air conditioning is ½ US gallon for each 3 kWh cooling demand. This is comparable to the cooling effect of direct evaporative cooling, as water contains **2.37 kW-hours of "coolth" per US Gallon.** A clear advantage of evaporative cooling systems are that they avoid the greenhouse gas emmisions associated with coal fired thermal power, and can be decentralized with rooftop harvesting to serve in-house demand for cooling. The disadvantage of evaporative cooling is that it does not perform during humid weather, but in such cases the demand for coolth could be complemented by vapour-compression systems. A building-integrated hybrid air-conditioning system (Williams and Stockwell 2004) demonstrated solar PV-array powered vapour-compression chilling of the sump water in conventional evaporative coolers to serve during muggy weather.

If nothing else, the present paper seeks to establish liquid water as a form of renewable energy which has the capacity to offset a substantial share of the demand for fossil-fuel power generation. In common with wind or solar energy, rainwater is of intermitant utility.
The demand for coolth delivered by water operates in competion with agricultural and metropolitian consumption, which have here-to-for resulted in damming of rivers to create water storages. Because dams are terribly disruptive to landscape and riparian processes, and suffer from large evaporative losses, it is worth considering alternative water resources.

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Desalination can recharge evaporating storages, and in the case of solar photovoltaic reverse osmosis (PV-RO), productivity is maximized in times of drought (Peterson and Gray 2012). Even in situations where the sea offers the only available water resource, reverse osmosis with energy recovery requires only 0.01 kWh per US Gallon permeate (2.5 kWh per kL, Geisler, et al. 2001), which is a small fraction of the coolth potential of the water delivered.

With the advances in rooftop solar electricity, peri-urban and rural developments are feasible off-grid, without water and power mains. Such developments concurrently require building-integrated rooftop rainwater harvesting and storage systems. There has been a long history of outback Australians dwelling without access to reticulated water, but not without tanks running dry at times of drought and fire (O'Brien 1921). A novel trans-climatic rainwater harvesting system design tool, accessed from the URL **http://GetTanked.org/**, has been developed (Peterson 2014) after reviewing the literature on the basis of established design tools, disaggregation of consumption into demand for potable and non-potable uses, and by assessing variability of rainfall and evapotranspiration across the continent of Australia. The methodology behind the rainwater harvesting simulations are outlined in Figure 1 includes a daily mass balance with reference to 121 years of meteorological observations throughout the Australian continent.

Global hourly monitoring of rainfall has commenced this year with Japan's launch of a core observatory satellite now in the process of providing calibration to a constellation of existing satellites so that their radar can measure light rain (Hou, et al. 2008). This should allow postprocessing of data from the Tropical Rainfall Measuring Mission, launched in 1997, that originally only measured moderate and heavy rainfall in the tropics. And so it is concievable that the rainwater harvesting tool could serve globally with reference to the last 17 years of rainfall.

Hourly solar energy has been calibrated to provide hourly direct and diffuse timeseries on virtually an location in Australia since 1990, and these data have been integrated with 80 meteorological ground stations in the Australian Climate Data Bank (NatHERS 2012, Liley, et al. 2013) as TMY2 files. Perhaps global rainfall datasets can be included in TMY files as global percipitation is calibrated. Presently very few hourly TMY archives provide unbroken records of percipitation, and so integrated simulation of rainfall and solar energy impact on the built environment has not progressed.

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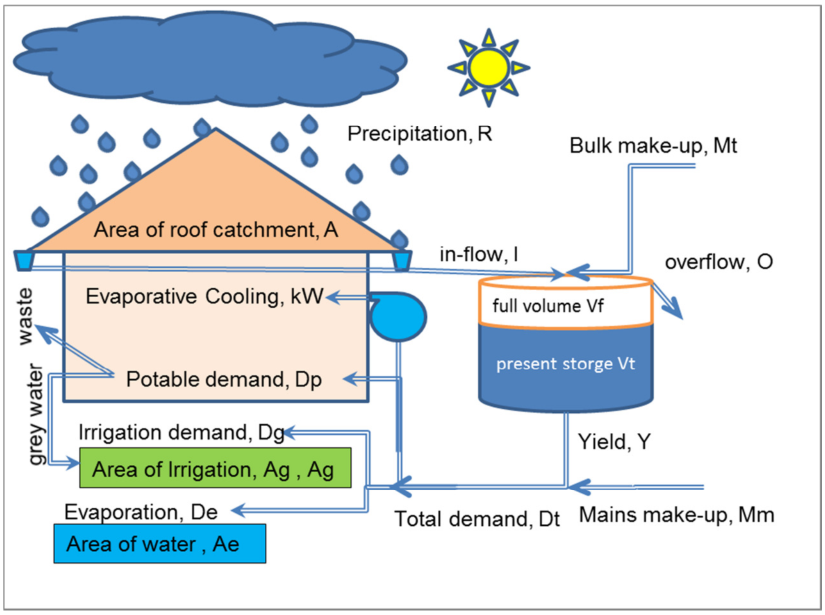

Figure 1: Rainwater harvesting and demand system modelled at http://GetTanked.org/

With respect to evaporative cooling, cooling load is calculate on the basis of base 24°C cooling degree days (CDD) and the design drybulb temperature (DDB) at any locality of interest. CDD and DDB are determined by the tool, but can also be determined from ASHRAE (2013), as an independent check. From this point it is assumed that the cooling rating of the evaporative cooler is suitably sized with respect to DDB, with building heat load, UA given in equation 1 as the rated cooling capacity kW per Kelvin ΔT.

$$UA = kW/(DDB - 24°C) \quad (1)$$

The displacement airflow of the evaporative cooling system is given in equation 2.

$$airflow = kW/(\Delta T \times \rho_{air} \times C_p) \quad (2)$$

Then equations 3 through 6 must be calculated for each day of the simulation.

$$\text{Cooling demand, } kW_t = UA \times CDD_t \quad (3)$$

$$\text{Cooling capacity, } kW = airflow \times WBCDD_t \times \rho_{air} \times C_p \quad (4)$$

$$\text{Delivered evaporative cooling, } kW_{evap} = \text{minimum}\{kW_t, kW\} \quad (5)$$

$$\text{Water use of evaporative cooler} = kW_{evap} \times 3600 \times 24/(LHE \times \rho_{water}) \quad (6)$$

Where the latent heat of evaporation, LHE is taken as a constant 2270 kJ/kg water. The demand of water used in evaporative cooling is thus determined if kW capacity requirement is known. The forgoing method does not determine the dis-satisfaction that may result from evaporative cooling, which may be considerable in hot/humid locaties. So it is necessary to identify such problem areas with the red overlay circles in Figure 2. The circles of this figure are classified by the kW capacity of an 85% effective direct evaporative cooler with 10³/hr air-flow, where the red circles denote locations with less than 1 ton capacity (3.5 kW). The map shows localities where evaporative cooling is effective, with over 22 kW capacity (blue circles) in colder climates of Tasmania and the Austrlian Alps. The area of application is more promising around the orange, yellow, and green circles but depends on the availablity of water with reference to the shades of grey that classify sustainable yield from cistern tanks.

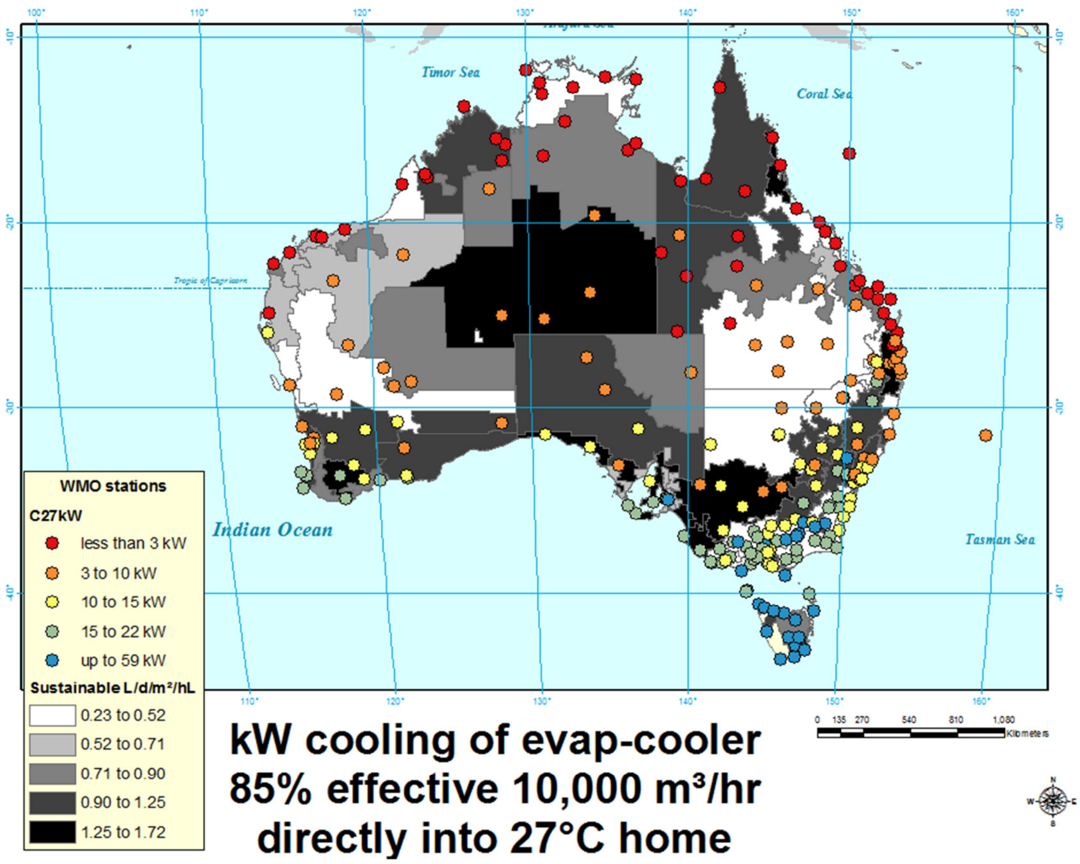

Figure 2: Direct evaporative cooler capacity plotted over grey scale simulated sustainable daily demand that can be delivered per m² catchment per hL cistern storage tank capacity. Circles are from locations of ASHRAE design data. Polygons represent regional performance based only on the assigned meteorological station of each NatHERS climate zone.

This map does not present the demand for cooling, which requires a detailed building thermal performance analysis. New homes that comply with the building code of Australia would be well served with 100 W/m² cooling capacity, or about 3 tons serving 100 m² dwelling. This map marks a red circle in locations where evaporative is ineffective due to humidity, and white in regions where rainwater harvesting systems would fail during dry seasons or drought.

HVAC system efficiency can be improved by exploiting the annals of the Australian Climate Data Bank (ACDB) that documents climate variability at 80 locations around Australia from

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1967 through 2012. In contrast, mid-20th-century design temperatures are listed in Table 1 of the AIRAH Handbook "DA09 Air Conditioning Load Estimation Application Manual".

DA9 Table 1 includes 60 hourly stations in Australia from which HVAC systems can be designed to suit critical conditions, while synthetic data was offered in Appendix Table 1B to cover 600 locations. DA9 Table 1 design conditions are generally based on 10 years of hourly observations, excluding meteorological data subsequent to the Australian Bicentennial.

Australian HVAC system design data website http://uq.id.au/e.peterson/ now increases the temporal coverage of HVAC design data by exploiting the ACDB, being a set of 80 high quality annals of hourly meteorological data that generally span 45 years (1967-2012) developed by Liley et al. (2013). This provides HVAC designers with design data to detail the current climate at 80 key locations, and track local changes with respect to the past 45 years in order to inform likely conditions mid-century-21. The methods presented here can be adapted to increase spatial coverage to 600 locations by working with the Bureau of Meteorology to process automatic weather station data.

In other cases, the Queensland Government's SILO database of thousands of rainguages instrumented with daily minimum and maximum temperature records can be used to estimate HVAC design conditions. This is delivered from the rainwater harvesting and demand calculator that has been developed at http://gettanked.org/ and by selecting "evaporative cooling" and specifying a nominal capacity. The use of daily maximum observations to estimate design conditions was detailed by Peterson et al. (2006).

DA9 includes 14 hourly stations that are not covered by the ACDB because they were closed manual stations. Consequently we will need to process Bureau of Meteorology automatic weather station data near the older manned stations to complete revision of Table 1 at these locations. A case study of urban heat island effects in the Brisbane capital city central business district illustrates the issues.

Conclusions

Rooftop solar PV systems may be required for climates which require vapour-compression dehumidification. Australian and New Zealand households' heating and cooling demands are well placed relative to the efficiency of heat pumps in analysis of the climate data files used in Australian and New Zealand house energy rating schemes (HERS). Design data are distilled from meteorological records to represent design conditions that are exceeded only rarely, but can also be derived from representative meteorological year (TMY) files. ASHRAE's (2013) analysis of World Meteorological Office database also informs the limits of evaporative cooling effectiveness, while TMY files provide bins of coincident parameters that measure the frosting of heatpumps. The design data are temperature, humidity and solar radiation coincident with extreme events. Design data are required for calculation of peak thermal demand of the built environment. to the HVAC systems and will be posted at http://suntank.org/ as they are developed.

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Glossary

ACDB	Australian Climatic Data Bank, solar radiation and surface meteorology
AIRAH	Australian Institute of Refrigeration, Air Conditioning and Heating
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
CDD_t	Cooling degree days with reference to base temperature ***t*** (generally 24 ° C)
Coolth	pleasantly low temperature
COP	coefficient of performance, ratio of heating or cooling delivered to electricity demand
DA	design aid, AIRAH technical manual for HVAC and refrigeration design
DDB	HVAC system design dry bulb temperature
HERS	house energy rating scheme, relative score of a residential dwelling's energy demand
HVAC	heating, ventilation, and air conditioning, technology of indoor environmental control
LHE	latent heat of evaporation, enthalpy to transform a substance from liquid to vapour
NatHERS	Nationwide House Energy Rating Scheme, Australian dwelling thermal performance
NIWA	National Institute of Water and Atmospheric Research, Lauder, New Zealand
PV	photovoltaic conversion of solar radiation into electricity using semiconductors
RO	reverse osmosis, water purification technology that uses a semipermeable membrane
R718	water used as the evaporating fluid in a refrigeration cycle
SILO	daily database of Australian climate data from 1889
TR	ton of refrigeration, heat-extraction capacity by melting 0.907 tonne of ice per day

TMY typical meteorological year, collation of hourly weather data for a specific location, generated from a data bank of many years duration. Consituent months are selected to presents the range of weather phenomena for the location in question, while still giving annual averages that are consistent with the long-term averages for the location in question.

UA	overall building fabric demand for cooling per increment outdoor temperature
US Gallon	customary unit of liquid capacity of the United States, 3.78541 litres

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A suitable design methodology for collective-self-organized housing projects to build sustainable districts

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Abstract: *Collective building has become more popular movement over the last twenty years particularly within the EU countries. There are different forms and typologies of such movements which have a changing degree of community profile, shared-values and expectations from the program of housing. When the energy-ambition is included in their programs, and embedded into the values of the community; collective housing carries a potential to be as grassroots movement towards building self-organized energy-efficient district via collective behaviour. In this paper, this potential movement is conceptualized as Collective Self Organized Housing (CSO). However, building sustainable districts collectively requires a design methodology which establishes strong and clear relationships among community, design professionals, suppliers, and municipalities. In this paper, firstly CSO design process is defined; secondly participatory design and concurrent design methodologies are reviewed in order to see their suitability to be CSO design process, and finally conclusions and recommendations are drawn to discuss CSO-specific design methodology.*

Collective housing, energy-efficiency, design

Background

A substantial sustainable housing movement has developed over the last 30–40 years with pioneering new ideas and experimenting with new practices (Seyfang 2010). There are fundamentally different discourses, practices, and governance of sustainability between these movements and mainstream housing provision; and these differences result in barriers to transfer the practices which encompasses ideological, cultural, social and ethical factors beyond economic and technical ones (Saffang 2010; Smith, 2007; Shove, 1998; Lovell, 2004). In such movements, there are also innovative design solutions which require behavioural changes (incorporating the behaviours of the end-users and the community), technological change (using and incorporating the technological developments and solutions) and institutional change (regulatory measures, and norms and energy taxes) (Ornetzedera and Rohracher 2006). Nevertheless, experiences of such changes, management interventions, and the innovations are not widely diffused (Seyfang 2010). Little is known about the drivers that are different in movements, the values that attach individuals to join to these movements, and the behaviours of the community governing the sustainability ambition and reflecting all these to their programs of their housing. And there is a need to better understand and therefore harness the creative energies of community-led solutions, and adapt them for wider mainstream settings (ibid). In other words, there is a limited understanding about how different communities lead their projects and incorporate available innovations in the design process. Consequently, there is a need to canvas existing movements, their typologies, driving values and expectations from their housing in order to identify a required design process for community-driven housing projects.

Below the common typologies of such movements are presented.

Cohousing is an end-user initiated, developed, and managed residential housing (Fenster 1999; Lietaert 2010). It has mixed programs of private and common dwellings to recreate a sense of community, while preserving a high degree of individual privacy (Lietaert 2010). Cohousing is driven by a modern-communal life style and requires equal degree of participation of end-users (McCamant and Durret 2011) and.

Common Interest Community is a community-led private real-estate development (Hyatt 1998; Paik 1998 in Fenster 1999), organized within an association created by either statute or covenants running with the land (Fenster 1999). The community becomes as an institutional client (McKenzie 2003) and is driven by the additional spatial and emotional characteristics (Brouwer and Bektas 2014).

Collective Housing is initiated by often municipalities to fulfil modernisation and gender equality such as less house work for women (Vestbro 2000). It is programmed as apartments around central kitchen, with food-lifts providing ordered food to each apartment; driving the collective and communal living.

Intentional Community is driven by a shared strong religious, political, environmental or social ideology rather than simply a desire to have a strong sense of community with their neighbours (Guinther 2008). There is no specific program demand by the community as long as the ideological group lives together in their own islands.

Collectively Commissioned Housing is driven byadditional functions and values, not represented in standard housing (de Haan & Tummers 2007). The driving force is the potential to be financially and institutionally strong as a collective group. Their programs include such additional spaces next to workspaces, garden, playground or bike stall, might also serve wider neighbourhood functionality.

Community-led Housing is formed to stimulate tenants and leaseholders to collectively take on responsibility for managing the homes they live in (NFTMO 2004). The tenants participate to the decision process, excluding major decisions. It is driven by cost-effectiveness, improved maintenance within short-term frame due to the tenancy period.

Self-build/provided Housing is driven by cost-effectiveness and affordability comparing to speculative housing provision. It becomes a major element in the expansion of European metropoles, and sometimes reaches the heights of 'post-fordist' industrial organisation and product development (Duncan and Rowe 1993).

Existing movements exemplified above have either community or program driven values. For example, cohousing, collective housing and intentional communities are on the community-driven side as the program is a tool to create the life-style the community desires. Whereas common interest community, collective-led/commissioned housing are on the program-driven side, as the enhanced program itself is an expected result due to the additional physical features that the community aim to have (i.e. controlled entries, surveillance, similar-income housing, affordability, more public spaces etc.).

None of the examples results in a totally unique programs but *new physical and social entities* in relation with their community profile, shared-values and the degree of their participatory behaviours from the perspective of design process. In other words, even if the categories are not univocal, each typology can differ by basing on some particular characteristics. These characteristics deal with:

- Higher/lower sense of community (the degree of community intention),
- Level of involvement of end-users (the degree of partication),
- Motivations/values which drive a group of individuals to start a collective process.

This can result in ideologically-driven communities or groups-driven by the potential of saving costs and/or having affordable and tailor-made design comparing with the traditional housing market. A major share of them presents shared facilities, as communal kitchen and laundry, or additional services to the neighbourhood. However, no matter how strong the interaction and participation of the community members with the commissioned parties are and how changing motivations they have, there are similar problems such as delays, standard solutions, or not reaching the full potential of aimed energy ambition in the end. Regarding the sustainability values, only few movements incorporated 'sustainability' as a value attached to the movement, except the examples in cohousing, eco-villages which evidently impose a certain ideology of either political or life-style.

The collective movements analyzed as Cohousing, Common Interest Community, Collective Housing, Intentional Community, Collectively Commissioned Housing, Community-led Housing, and Self-build/provided impose a certain typology and categorization to the future collective groups who focus on deliberate sustainable living and building. Thus, there is a need for an umbrella concept that doesn't impose any ideology, typology, life-style explicitly, yet generic enough to associate community members to the potential projects and drive the whole development process towards their requirements at district scale, which incorporate governance of sustainability. Below, this umbrella concept is called as *Collective-Self-Organized Housing*.

Collective-Self-Organized Housing

The term Collective-Self-Organized Housing (CSO) refers to a housing model characterized by a high level of self-organization and participation of the end-users in the processes of formation, requirements definition, planning, design, implementation and maintaining their own housing project at district level. CSO is used as an umbrella term that encompasses multiple housing typologies, incorporates energy efficiency, and the movement driven by a group of individuals who organizes community forming, pre-design, design, construction and

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operational phases with changing degree of participation. CSO housing can be either new construction or retrofitting of existing buildings at district scale. In other words, community in CSO housing obtains a high degree of customization of the private and common spaces at the district scale and involves in a tailor-made design process, which incorporates their values.

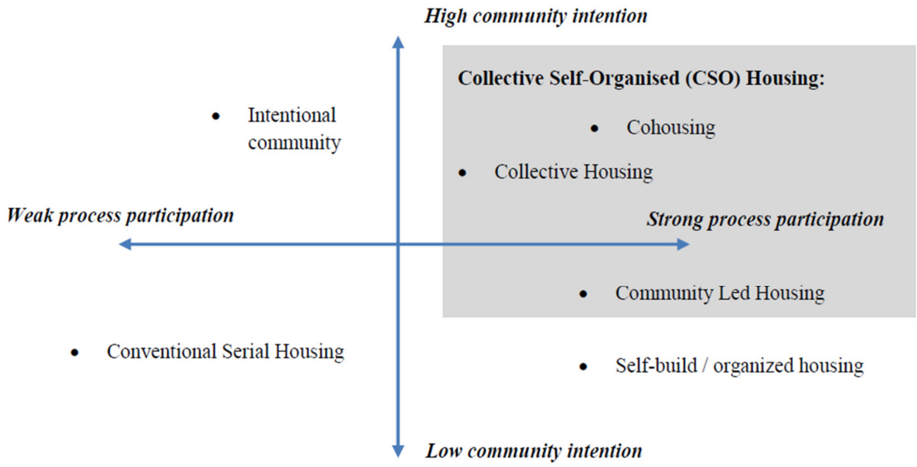

Figure 1 representation of mapping grassroots housing movements with explicit defining area of CSO Housing (Brouwer and Bektas 2014).

Brouwer and Bektas (2014) identified four dynamics that provides interplay in each CSO housing projects; 1) values, 2) behaviours, 3) community, and 4) program as illustrated in Figure 2. These four aspects are reflected in design process either being tangible (i.e. program of the community) or intangible characters (values, behaviours) of projects.

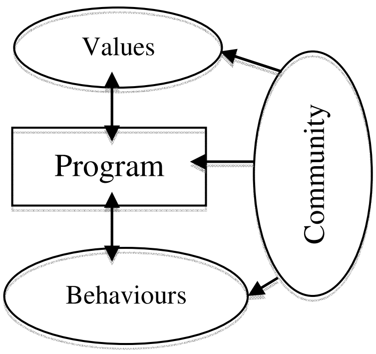

Figure 2 Four typical dynamics influencing the design process of collective housing movements (Brouwer and Bektas 2014).

Regardless of the political, ecological or social ideology, CSO housing becomes a tool to build and/or transform existing districts to sustainable districts. However, there are two critical predictions in CSO Housing conceptualized here:

1. As CSO housing is a conceptual term that embraces existing grassroots movements, the current problems of existing movements remain the same, unless they are addressed particularly. (i.e. being a once-a-life time project in which the lessons are learnt yet not transferred anywhere; facing with excessively long and costly projects; ending up with mismatches between expectations of community and design solutions

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provided by the design professionals when the values and behaviours are not well-understood and reflected to the design; difficulty to have realistic energy ambition in their programs.
2. As currently the community (the non-professional end-users) has limited access (and insights) to the businesses and suppliers that are innovative and skilful to apply novel total solutions, CSO housing has a danger to end up very standardized design solutions than being innovative.

These predictions highlight the importance of finding a suitable design methodology that bridges community expectations and practice of design professionals (including architects, engineers, suppliers, ESCO's etc.); and that provides the intended degree of participation and concurrency between these actors in CSO projects.

Design Process of CSO Housing

The design process of CSO Housing requires a high -yet changing- degree of participation of end users, and intensive interaction among design-disciplines due to their program embedding innovative technologies for sustainability. It also embraces a high degree of iteration in design activities. Depending on the profile of the community, their values, and expectations from their programs, the degree of participation is required. This degree influences their behaviours to the design process.

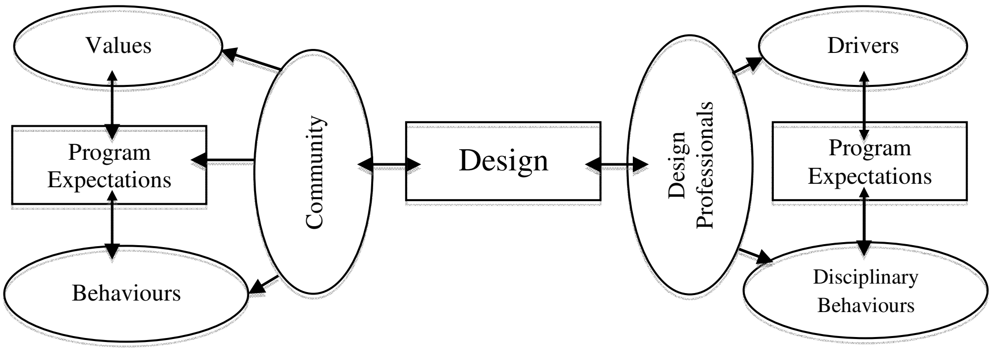

Figure 3 the focus of concurrent design in CSO housing projects, adopted from Brouwer and Bektas (2014)

The interplay of CSO housing (among values, behaviours, community and program) of Brouwer and Bektas (2014) are from the perspective of the community, and it does not include the perspective of design professionals. Below in

Figure 3, we enhance this interplay through including design professionals, which also have changing values, driving forces, disciplinary behaviours and program expectations.

In CSO projects, *design* itself becomes a mean to communicate, externalize both sides' expectations and reflect their values. As participation becomes crucial from the perspective of community, participatory design methodology becomes evident to be reviewed. As interdependency between design disciplines (i.e. building, installation, materialization) and the iteration managed with end users become crucial for the design professionals' perspective, concurrent design methodology becomes evident to be reviewed.

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Participatory design methodology for CSO housing

Participatory Design (PD) is an end-user-oriented design methodology that places a premium on the active involvement of end-users in design and decision-making (Sanoff 2008). Kensing and Blomberg (1998) claim that PD is one of the preconditions for good design and increases the likelihood that buildings will be designed and built useful and well integrated into the daily practice of residents. CSO housing is conceptualized as an emerging sector due to the freedom the end-users experience in expressing their demands and wishes into formulating the ideal housing process, housing design and forming of a community. This freedom becomes the participation space of end-users. PD promises a profound involvement of the end-users in the design, accordingly to the rules of participation established between the end-users and design professionals, and provides tailor-made solutions.

PD in CSO housing would be interpreted as a method that end users participate actively to the design process accordingly to the rules of participation established between the end-users and design professionals. PD in CSO housing at least involves the design disciplines (architect, structural engineer, technician, building physics) and the envisioned end-users (owner occupants, services). Thus, the participation deals with the integration of the perspectives, knowledge and insights of the supply and demand side. The aspects of PD in CSO housing in this sense become reality by agreeing upon 1) definition of the extent of participation rules between actors, 2) agreement on the form and degree of participation 3) selection and the use of the tools and methodologies in participatory design, by both supply and demand side. PD in any CSO housing project is a tailor made solution, depending on the requests of the demand side, and a certain pre-fixing of solutions and design freedom from the supply side.

In terms of requirements to facilitate the principles of PD in CSO housing, the community (as CSO client) is free to choose which degree of participation they wish to have in their CSO projects. This degree in the design process depends on the willing of the community and the rules of participation they set up. The participation in CSO housing deals with the whole collaborative design process, not only focus on the collective decision-making process. But even in collective decision-making process, there are preparation requirements. Any collective decision-making process requires having a choice, between a set of alternative solutions, and/or in defining the problems (articulation) as in the program of requirements. The interplay between problem definition, solutions design and selection between alternatives (on various abstraction levels) is the key for a successful design process. This brings a crucial treatment to the program of requirements in CSO housing, as it is a collective outcome of end-user requirements. Therefore, PD requires accepting that the program of requirements in CSO housing changes over time and managed with dynamic briefing principles.

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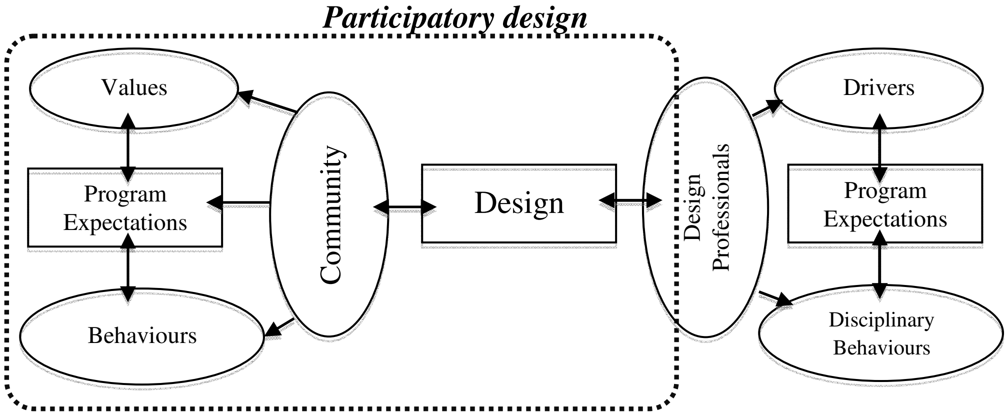

Figure 4 the focus of participatory design in CSO housing based on Brouwer and Bektas (2014)

Concurrent Design methodology for CSO housing

Concurrent Design (CD) is a multidisciplinary integrated approach to embed technology constraints, cost, risk and planning to the design for complex projects (Matthyssen and Gerené 2011). In product development context, CD is defined to incorporate the considerations in the downstream product development phases (i.e. manufacturing, assembly, maintenance, etc.) into the design phase for producing a design with the best overall product life-cycle performance (Xue et al. 1999). Thus, it deals with enrichment of the design information earlier rather than convention manner as it occurs over time across the phases. Matthyssen and Gerené (2011) emphasize it on management perspective and the need for CD in complex projects due to their notoriousity in management performances (See: Flyvberg 2002, Flyvberg et al. 2003), whereas Xue et al. (1999) deal with the early integration of the information that normally produced (or made explicit) through the elaboration of the design solutions.

As Finger et al. (1995) identify, CD consists of two views: 1) organizational and 2) technical. From the organizational point of view (1), CD creates and organizes team of professionals, which develop parallel and synchronous activities. From the technical point of view (2), the team is expected to organize itself creating and integrating computer-based tools to share a common ground for knowledge. Contrary to the traditional design method, it involves the opportunity of overlapping the activities, thus the removal of information dependency between different activities, allowing the collaboration among different field of expertise (Bogus et al. 2005). This leads us to the two levels that CD is related to: 1) project management and 2) design management and evolvement. Depending on which view the project team looks through, the implementations and the expected benefits can vary. Below, we try to understand what CD's benefits are in projects.

The benefits listed above deal with different actors (i.e. client, design team, contractor) in different levels in projects (i.e. organizational –'corporate'). It deals with firstly the client (as referred to 'customer') with higher satisfaction and quality, reduced risk; secondly the design team with managing re-design and iteration ('reduction'), evaluation of more design options and thirdly the contractor with standardization of methods and the design model that integrates multi-disciplinary knowledge. Besides, the employee efficiency and involvement cross-fertilizes the benefits that differed to each actor.

However, this essential aspect, and promising potential of concurrent design, is not fully utilized, often due to time and organizational constraints in projects. CD requires an attentive calibration between benefits and risks as the incorrect organizational structure could instead bring to waste in terms of money and time, not guaranteeing the results. These connect us to the requirements of CD in relation with the view of CD.

The key issue in CD is to integrate design information in early stage. This information deals with the assembling, maintenance and operation and indicates the projects actors (client, design team and the contractor) about the management performance indicators such as cost, time, quality, etc. In order to do that CD identifies activities to be synchronized and/or parallel run. Two things are required for this; 1) identification of activities and 2) management plan.

Thus, CD requires a decision-making structure definition to support collaboration. Through tools, plans and identified activities, decomposition of assignments (task and activity) and the synthesis of different solutions are done. These concurrent activities allow for a faster and shorter-cyclic iteration, through which more synchronous and coherent effort can be achieved.

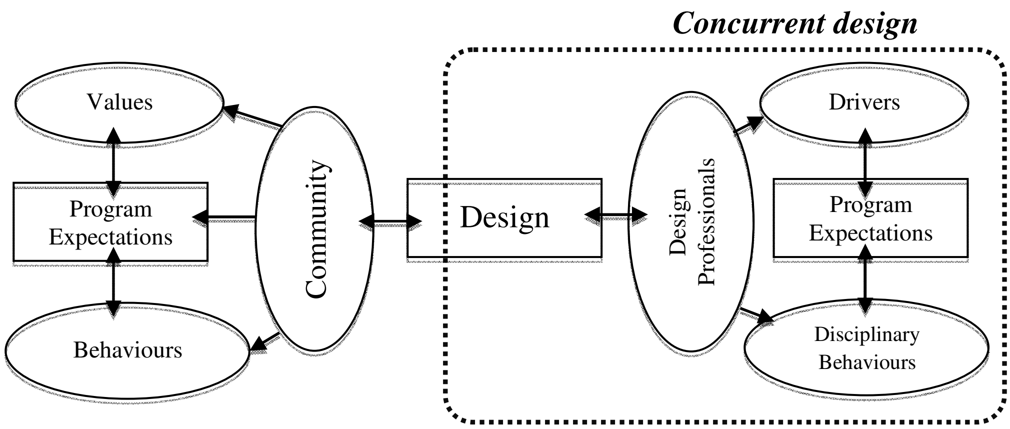

Figure 5 the focus of concurrent design in CSO housing based on Brouwer and Bektas (2014)

Besides the collaboration with the design professionals, the collaboration with suppliers entails the integration of process and products speeding up the timing and fixing the cost of the investment. The synchronous and parallel development of different knowledge entails less iteration among activities, speeding up the process. All the different disciplines work concurrently to the definition of the project achieving also a better fulfilment of the requirements of the end-users and the response to their expectations. Moreover, the "cost" factor is prevailing in a CSO project as late changes in cost could achieve the failure of a project.

So far, CD in CSO housing seems promising for collaboration among design professionals from the early beginning of the design phase. Moving from promising to be a suitable approach, definition of roles and responsibility of each actor become crucial for the coordination and activities development mechanism. Thus, CD in CSO housing requires 1) initial definition of upfront requirements, 2) a flexible set-based design and 3) an organizational and technical tool to develop the design activities. The proper definition of these upfront conditions (project constraints and potentials, requirements) (1) entails less design changes in case of downstream information/requirements changes which could be better fulfilled within a (2) flexible system.

Discussion & Conclusions & Recommendations
Both methodologies have a different focus in CSO housing projects, as PD focuses on participation of end-users, whereas CD deals with collaboration of all the disciplines in the different project phases. On the one hand, PD reflects a key role of the end-users, ensuring their involvement in the design process, from the early beginning, up to the construction phase. On the other hand, CD provides a suitable basis for the integration of social, economic, and technical knowledge in the design process establishing a parallel work-setting instead of a traditional hierarchical, sequential order of steps and incorporating the knowhow of disciplines from the end of the design and building process (materials, details, management and maintenance) as far as possible to the beginning. Subsequently, neither participatory nor concurrent design methodologies fully fit to the interplay of CSO housing projects.. Neither one supports the facilitation between CSO housing clients (communities attached to their values and behaviours to the design process) nor design professionals, which also have disciplinary behaviours, program expectations and own drivers, together.

The main difficulty in combining PD and CD is that collaboration essentially presupposes definition of requirements as far upstream in the process to enable professional parties to deal in parallel with tasks; whereas the main characteristic of PD regarding non-professionals end-users is that these requirements cannot be decided and fixed far upstream in the process. Thus, these operate on two different levels. In these two level operations, a specific methodology and innovative tools would be necessary to provide concurrency among parties, participation of the community and programming which makes the values explicit.

If we can elaborate, from demand perspective, this common level needs to correspond to the quality of site, buildings and dwellings; and focus of programing which consists of functionality (i.e. lay-outs, common spaces, accessibility, etc.), sustainability (the energy-ambition of the community) and deals with the dynamic definition of programs of community. From supply perspective, this common needs to correspond to design quality, the construction process, technological solutions, characteristics and specifications of materials and components, energy performances of building systems, and deals with iteration of program driven by the community not only the design itself. One of the solutions would be focusing on building systems within districts and how to make more familiar concepts to boost the interaction and understanding between both. One example would be to perceive a building system and its neighbourhood as a technological (e.g. structural framework, external envelope, etc.), functional (homogeneous areas and single spaces/rooms), and social (values

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tangibly presented in building systems and neighbourhoods) subsystems. When the activities with supply and demand side explicitly focus on these three subsystems, actors of both sides can communicate via “functional, spatial, and social-relation entity” in the design process. This three-relation entity becomes a bridge which externalizes both the expectations of non-professional actors and the knowledge of design professionals.

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Study on proper allocation of non-energy benefits supporting stakeholders' consensus building to promote community-wide sustainable energy systems

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Abstract: *Community-wide energy utilization is expected to contribute further energy saving, lower carbon intensity and self-reliance of the energy supply in the community for promising its sustainability and resiliency. One of the major hurdles of a community-wide energy utilization project is that it requires consensus at the planning phase among stakeholders such as land owners, building users, energy service providers, local government relating to the project. There are variety of co-benefits including non-energy benefits (NEBs) such as* CO_2 *emission reduction, stimulation to the local economy and energy supply security of the community. This study describes the promotion measures to motivate consensus building among stakeholders through proper allocation of cost and co-benefits (EB and NEBs), in consideration of uncertainty at the planning phase. The effectiveness of the proposed measures is verified through a case study based on an actual project.*

Keywords, community-wide energy utilization, co-benefits, non-energy benefits, cost-benefit ratio, stakeholders, risk allocation

1. Introduction

In the commercial and residential sectors, further carbon emission reduction measures are being sought toward the realization of a sustainable low-carbon society. One particularly promising measures is “community-wide energy utilization”. To exchange power and heat locally among neighborhood, district and city scale is expected to be quite effective for further energy conservation and CO_2 reduction to the level which a single building would never achieve.

However, community-wide energy utilization is yet to be commonly developed that is expected. As described in the literatures [1) 2)], to achieve consensus of stakeholders, it is critical to spread recognition regarding a variety of co-benefits among stakeholders. Co-benefits consist of “energy benefit (EB)” (e.g. saving expenses for energy consumption) and so-called “non-energy benefits (NEBs)” (e.g. indirect economic benefits stimulated by measures and benefits to conserve the environment). Our former study [3)] focused on methods to evaluate NEBs converted into monetary value and demonstrated the idea that the effectiveness of community-wide energy utilization can be assessed by cost benefit ratio (B/C) in consideration of NEBs. As a following study, this paper focuses on measures for properly

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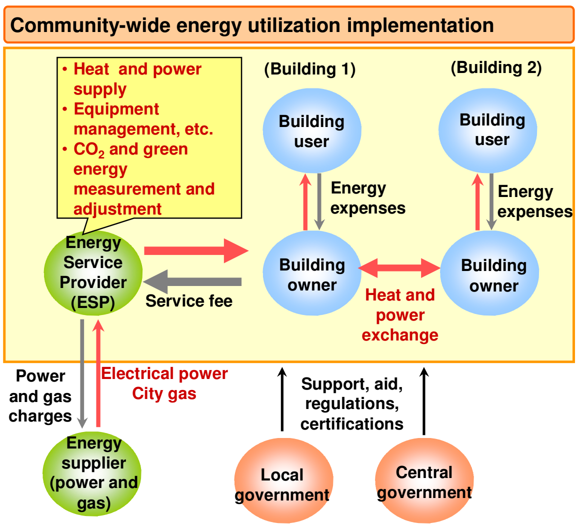
allocating costs and co-benefits (EB and NEBs) among stakeholders, and quantification and adjustment of risks in consideration of B/C uncertainty for each stakeholder.

2. Identification of recipients of co-benefits among stakeholders

Community-wide energy utilization involves more diverse stakeholders than those involved in a single building in the planning process of formulation. Figure 1 shows the correlations between stakeholders involved in community-wide energy utilization. We should note that not all stakeholders can equally obtain the co-benefits (EB and NEBs), meaning that the recipient of the NEB varies. As an example, the table in Figure 1 shows major recipients of co-benefits. Each stakeholder has a different recipient of benefits. Therefore, even if a favorable B/C is achieved for the project as a whole, this does not necessary mean that a consensus can be reached, which in turn means that adequate allocation of cost and co-benefits is still required. Particularly in the project planning stage, the planned amount of costs and co-benefits are subject to uncertainty. It should be considered that uncertainty can be a risk and that allowable B/C varies by stakeholder must be considered.



Co-benefits	Major Recipients for the co-benefits					
	Building Owner	Building User	Area ESP	Local government	Central government	Public visitors
Energy benefits (EB)						
Reduced power and gas expenses	X	X	X			
Non-energy benefit (NEBs)						
a. NEBs for creating environmental value						
a1. Benefits from reduced CO_2	X	X	X			
a2. Value pf creating green energy	X	X	X			
b. NEBs from ripple effects in the local economy						
b1. Ripple effects of business investment				X	X	X
b2. Ripple effects of running ESP projects				X	X	X
b3. Benefits from increasing value of land		X				X
c. NEBs from risk avoidance						
c1. Contributing to local BLCP*	X	X	X	X		X
c2. Avoiding risk against stricter regulations	X	X				
d. NEBs stemming from promotion and education						
d1. Benefits from education				X	X	
d2. Benefits from advertisement	X	X	X	X		

Note: BLCP : Business and Living Continuity Plan

Fig 1 Sample image of stakeholders relations and major recipients of co-benefits

3. Case study for multilateral stakeholders' co-benefits

3.1 Case study overview based on an actual project

As a reference, the following describes a case study using an actual project described in a literature[4)] that created a thermal exchange between two buildings with different owners. Figure 2 gives an overview of the project for the case study.

The model building is a 25-year-old office building in Kumagay, Japan (three stories, total floor area of 1,400 m^2). The building is undergoing a massive renovation plan for its heat source system. Due to a revision to the Energy Conservation Law in May 2008 which covers buildings with a total floor area of less than 2000 m^2, the building owner was urged to make drastic improvements in energy conservation and CO_2 reduction during the renovation, then

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finally decided to demonstrate an advanced solar-cooling air-conditioning system supported by a leading energy service provider (ESP) company. Solar heat utilization systems have excellent features, including higher energy efficiency per unit area than PV when the site have major cooling and heating demand. In contrast, installing solar heat collection panels as much as possible in consideration of peak cooling demand would result in excess heat collection, since in the typical office building, less demand is expected on weekends and during seasons with mild weather such as spring and autumn.

Taking advantage of its superior location, built next to a hotel with mass need for a hot water supply (hereinafter referred to as the "neighboring building"), a thermal exchange project was planned between the buildings by use of hot water conduits pipes and the thermal exchanger installed between the building. This project needs to obtain installation permits from the local city government for thermal exchange conduit pipes under a public road in spite of the purpose of private use.

Figure 2 shows expected annual energy conservation and reduction of CO_2. If the model building does not implement thermal exchange with the neighboring building, the excess solar heat on weekends and during seasons with mild weather would not make any contribution to energy conservation and CO_2 reduction. In comparison, even very small scale community-wide energy utilization, this project was estimated that approximately three times more energy saving and CO_2 reduction than the case without thermal exchange.

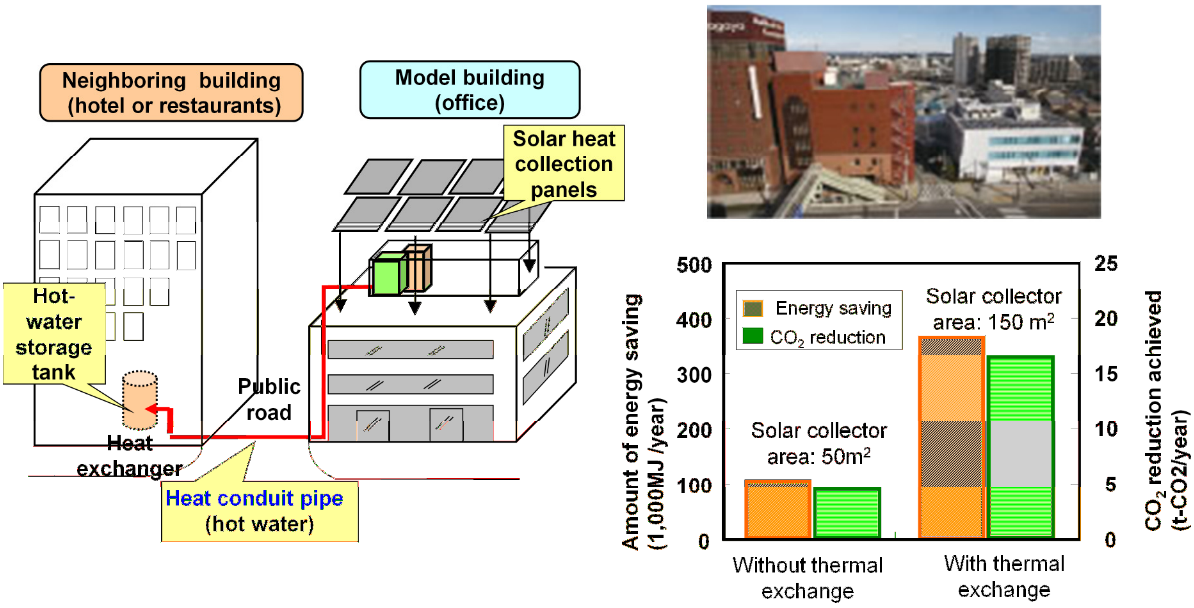

Figure 2 Overview of a case study project – thermal exchanging system and expected performance

3.2 Project B/C as a whole

Figure 3 shows the project overall B/C calculation results in this case by use of the calculation methods in our former study[3)]. It also shows comparative results between sizes of solar heat collection panels as well as the results of the project. Standard construction expenses required for cost calculations were determined based on the existing literature and values obtained

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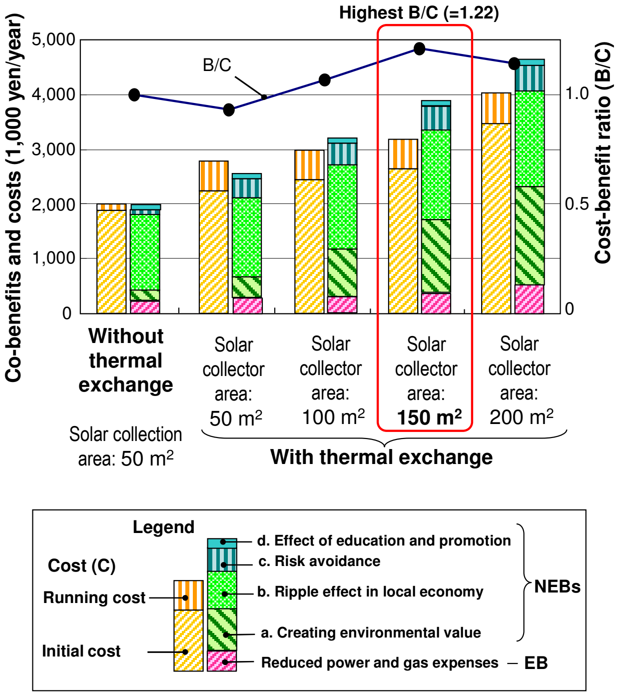
through actual projects. Also, co-benefits (EB and NEBs) are based on the evaluation method calculating monetary value. According to Figure 3, the maximum B/C would be 1.22 when the collection panel area was 150 m^2. This is because too much installation of panels with larger than 150m^2 on the model building would require structural reinforcement resulting in additional costs, pushing down the B/C.



	Project as a whole	by Stakeholders 1) A	B	C	D	E
Cost allocation						
Initial cost						
Solar collectors, heat source renovation2)	1	1/4		1/4		1/2
Thermal exchange conduit2)	1			1/3	1/3	1/3
Running cost						
Amount of area ESP to be paid3)	1	2/3	1/3			
Co-benefit allocation						
Energy benefit (EB)						
Reduced power and gas expenses4)	1	2/3	1/3			
Non-energy benefit (NEB)						
a. Creating environmental value 5)	1	7/8	1/8			
b. Ripple effects in economy	1				1/5	4/5
c. Risk avoidance 4)	1	2/3	1/3			
d. Effect of education and promotion	1	1/5	1/5	1/5	1/5	1/5
Calculation results for B/C	1.2	1.0	1.6	1.4	1.4	1.0

Notes :
1) Stakeholders A: Model building B: Neighboring building C: Area ESP D: Local government E: Central government
2) Using subsidy referring actual financial support program
3) Set project term of urban area to 10 years, based on an actual project
4) Allocated according to ratio of running costs incurred
5) Allocated according to ratio of total costs incurred

Figure 3 Expected project B/C and initial allocation of cost and co-benefit among stakeholders

3.3 Cost and co-benefit allocation by stakeholders and B/C

Based on the analysis above, for this case, it was confirmed that B/C exceeded 1.0 through the project. However, in the process of reaching consensus among stakeholders, a policy for allocating costs and co-benefits must be accepted. Given this, in consideration of actual ESCO projects, the following concepts are proposed for cost(C) and co-benefits (EB and NEBs) allocation

1) To ensure that B/C by stakeholders are roughly the same as the expected value for the project as a whole (1.22)
2) Local and central governments provide financial support to a part of initial and running costs in the form of subsidies, tax reduction considering the value of NEBs obtained from economic ripple effects
3) The both buildings pay for running costs in the form of the payment of ESP's service

It is reasonably acceptable that EB, NEBs of creating environmental values, and NEBs of risk avoidance and EB are allocated in accordance with the ratio of cost paid by each stakeholder. Table in Figure 3 shows an example of cost and benefit allocation and calculation results of B/C for each stakeholder. It shows that even distribution of B/C among stakeholders is

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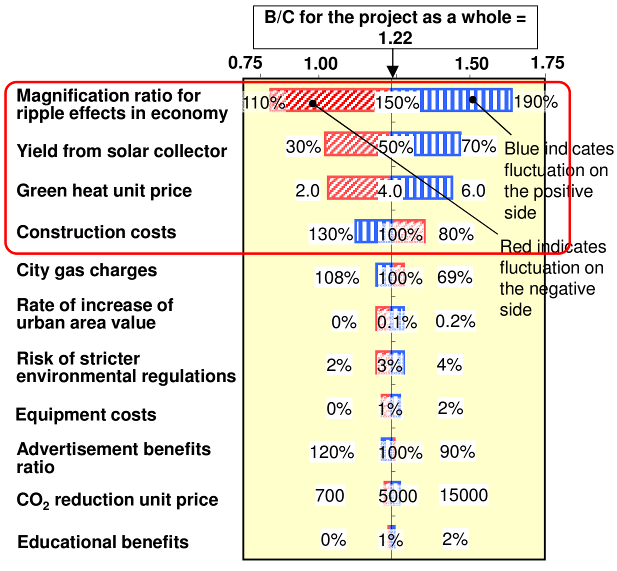
possible, despite the fact that those who are responsible for project initial and running costs are often different from those who receives NEBs in actual cases.

4. Co-benefits reallocation in light of varying risk tolerance among stakeholders

Predicted values used in this case study include a certain amount of uncertainty, which results in a risk. Normally, each stakeholder has a different amount of risk tolerance, thus it is considered critical to visualize this range for consensus building process. This concept is verified through the case study.

4.1 Identifying sensitive factors with uncertainty of the projects

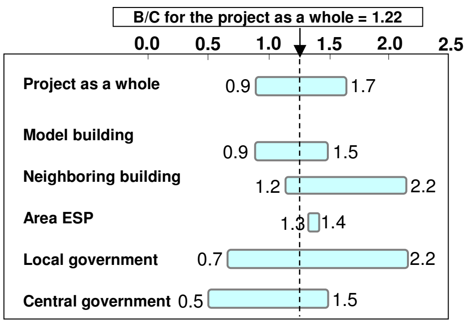
A sensibility analysis was conducted by calculating the range of fluctuation in B/C corresponding to the uncertainty of each factor. Figure 4 shows the results of B/C fluctuations for the project as a whole sorted in descending order. It suggests that in this case, the following factors are more sensitive to B/C: magnification ratio for ripple effects in economy, yield from solar collectors, green heat unit price, and construction costs.



Sensibility analysis for B/C against fluctuation ratio of factors with uncertainties

Probability distribution set by fluctuating factors

Factors with uncertainty	Probability distribution	Predicted fluctuation range
Magnification ratio for ripple effects in economy	Normal	Mean value μ = 150%, standard deviation σ = 20%
Yield from solar collector	Normal	Mean value μ = 50%, standard deviation σ = 10%
Green heat unit price	Triangular	2-8 yen/MJ Setting maximum-likelihood at 4 yen/MJ
construction costs	Triangular	90-120% setting initial predicted value to 1



10%-90% of the B/C cumulative probability distribution by stakeholders

Figure 4 Influential factors' sensitivity to B/C and probability distribution of B/C by stakeholders

4.2 Visualizing risks by stakeholder

Based on the above results, a probability distribution was set up for the particularly influential factors. A Monte Carlo simulation was then conducted using the probability distribution to calculate B/C fluctuation ranges for each stakeholder. Figure 4 shows the results of the Monte Carlo simulation conducted up to 10,000 times using Crystal Ball$^{(TM)}$. It illustrates fluctuation ranges equivalent from 10% to 90% of the B/C cumulative probability distribution by stakeholders as risk. As shown in Figure 3, the expected B/C value for each stakeholder

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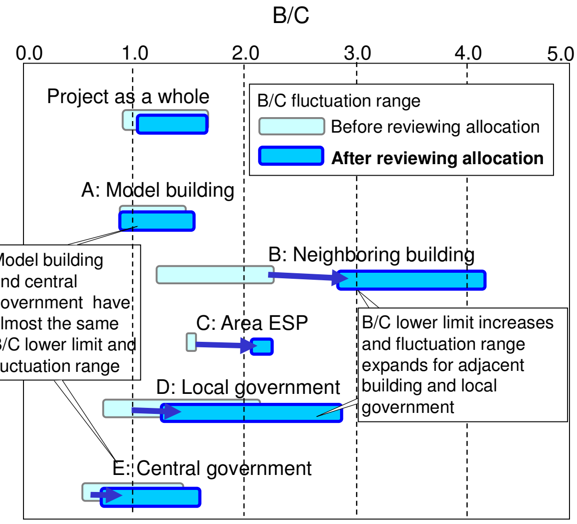
approximately reached that of the project as a whole (1.22). However, risks vary by stakeholders in the form of differences in fluctuation range.

4.3 Reallocation of cost and co-benefits considering risk tolerance for each stakeholder

The allocation shown in the table of Figure 3 may seem fair from the perspective of expected B/C values; however, stakeholders' perceptions of opportunity costs related to their own risk tolerance are different so that they are not always able to reach agreement due to differences in expected B/C and risk tolerance created by restrictions in their own financial situations.

	Project as a whole	by Stakeholders A	B	C	D	E
Cost allocation						
Initial cost						
Solar collectors, heat source renovation	1	1/2				1/2
Thermal exchange conduit	1			1/3	1/3	1/3
Running cost						
Amount of area ESP to be paid	1	2/5	1/10			1/2
Co-benefit allocation						
Energy benefit (EB)						
Reduced power and gas expenses	1	2/3	1/3			
Non-energy benefit (NEB)						
a. Creating environmental value	1	3/5			1/10	3/10
b. Ripple effects in economy	1				1/5	4/5
c. Risk avoidance	1	2/3	1/3			
d. Effect of education and promotion	1	1/5	1/5	1/5	1/5	1/5
Calculation results for B/C	1.2	1.0	2.8	2.1	2.0	1.1

Notes :
Dotted boxes areas are proposed re-allocation based on stakeholders' risk tolerance



10%-90% of the B/C cumulative probability distribution by stakeholders

Figure 5 Reallocation of cost and co-benefits and expected fluctuation of B/C by stakeholders

Given this reality, the feasibility of adjustment was considered by reviewing the allocation of C, EB, and NEBs. Using the actual process of project formulation as a reference, this case was assumed to satisfy the following conditions among stakeholders.

1) The neighboring building desires to have its B/C higher than 2.0 at 90% probability
2) The local government desires to have its B/C higher than 1.2 at 90% probability
3) Stakeholders incur a part of running costs and in return, they get NEB (a. creating environmental value) at a certain ratio, while central and local governments will incur a part of running costs.

To achieve this, the local government gets an NEB (a. creating environmental value) at a certain ratio. In return for subsidizing the initial cost of the thermal exchange conduit, the government gets an NEB (a. creating environmental value) at a certain ratio. Table in Figure 5 shows a preliminary review of the C, EB, NEBs allocation and the results of the B/C calculations based on the above policy. The neighboring building and local government are expected to be satisfied with their risk tolerance range (i.e. lower limit: 2.0 and 1.2

respectively). On the other hand, the B/C fluctuation range for these two grew, while the ranges for other stakeholders remained almost same.

From the results described above, it suggests clearly that risks can be adjusted by modifying the allocation of C, EB, and NEBs for each stakeholder.

5. Conclusion

In order to promote promising community-wide energy utilization as an additional low-carbon path in the commercial and residential sector, with a focus on co-benefits (EB and NEBs), this study contains the following key points, to be brought from the measures:

1) Allocation method is critical for consensus building among stakeholders. This study demonstrated an idea for allocating cost and co-benefits to spread B/C almost equally among stakeholders, while considering differences in NEBs recipients when allocating cost and co-benefits.
2) Risks between stakeholders can be adjusted by reviewing the allocation policy in consideration of: (1) B/C fluctuation risk derived from uncertainty in values predicted for preliminary calculation of cost and co-benefits, and (2) variance in risk tolerance of each stakeholder.

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Baseline Analysis for Deployment of a Scalable and Modular Dedicated BMS in Sport and Recreation Buildings

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Abstract: *The European Sport and Recreation Buildings are unique by their physical nature, their energy consumption profiles, the usage patterns of people inside, and comfort requirements. Sporte2 project aims to manage and optimize the triple dimensions of energy flows (generation, grid exchange, and consumption) in Sport and Recreation Buildings by developing Sporte2 System, a new scalable and modular Building Management System(BMS). Our paper describes the methodology designed for the deployment process that involves the baseline analysis based on the results of the dynamic simulation of the selected optimization scenarios. The simulation model includes the architectonic and constructive definition of the facility, the characterization of the activity and the modelling of the systems involved in the scenarios. This activity influences all the design decisions to be taken in the service deployment process and the final potential of the service in terms of energy efficiency, costs reduction and user satisfaction improvement.*

BMS deployment, analysis methodology, dynamic simulation, energy efficiency, comfort improvement, sport and recreation buildings

Baseline Analysis Process

The European Sport and Recreation Buildings are unique by their physical nature, their energy consumption profiles, the usage patterns of people inside, and comfort requirements [1]. Sporte2- 'Intelligent Management System to integrate and control energy generation, consumption and exchange for European Sport and Recreation Buildings' project aims to manage and optimize the triple dimensions of energy flows (generation, grid exchange, and consumption) in Sport and Recreation Buildings by developing Sporte2 System, a new scalable and modular dedicated Building Management System (BMS) based on smart metering, integrated control, optimal decision making, and multi-facility management. This system enables a new relationship and business model structure between facility managers and power providers.

A methodology has been designed for the deployment process of the Sporte2 system in sport and recreation buildings. The Sporte2 system has been deployed for testing and validation in a two steps process in the project. First, a prototype of the system has been deployed in a full scale building laboratory environment (Kubik by Tecnalia) for system integration and testing and then, the system has been installed in three full-scale pilots that are representative of the sector.

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The proposed methodology involves the analysis of the baseline of the sport facilities based on the results of the dynamic simulation of the selected optimization scenarios. The simulation model includes the architectonic and constructive definition of the facility, the characterization of the activities and the modelling of the operation and management of the systems involved in the scenarios. The simulation process enables the characterization of the activities and systems existing in the facilities under different conditions and the necessary process of deficiency and improvement opportunity detection.

This analysis is the first step of the Sporte2 service deployment process, and it is of crucial importance as it will strongly influence all the design decisions to be taken in the subsequent stages, and therefore, the final potential of the Sporte2 service in terms of costs reduction (energy and water savings and maintenance need reduction) and user satisfaction improvement. The activities defined to perform the baseline analysis process [*Figure 6*] should be carried out in three phases:

- Baseline Scenario Analysis
- Optimization Scenarios Definition
- Scenarios Modelling and Simulation

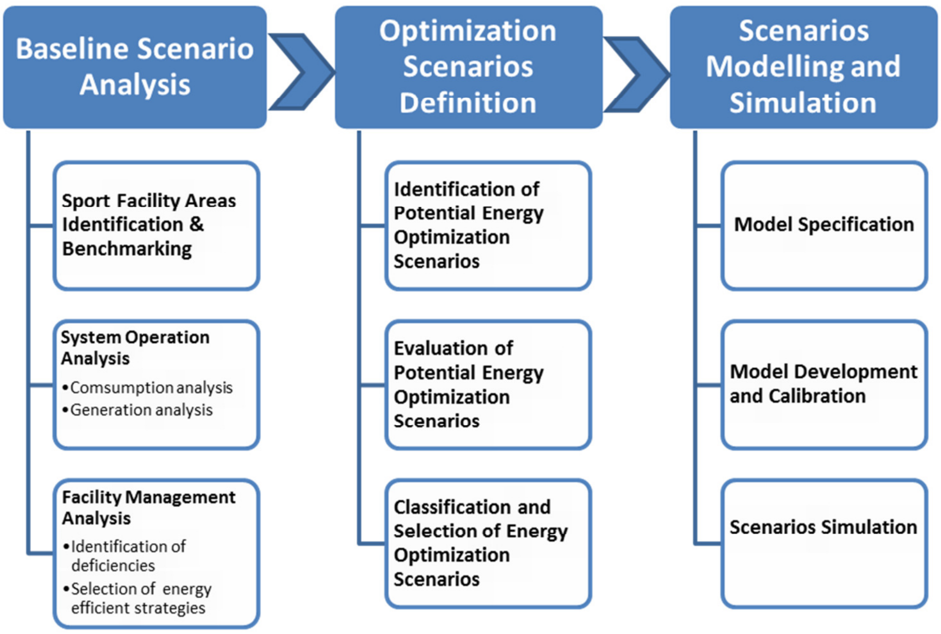

Figure 6 Baseline analysis process activities

Baseline Scenario Analysis

The final objective of the Baseline Scenario Analysis is to acquire a deep knowledge and understanding of the activities developed in all the areas of the Sports facility (fitness room, swimming pool, multi sports court, etc.) from the perspective of usage characterization (occupancy profiles, user characteristics, etc.) and required services (comfort level, internal air quality, etc.). The analysis covers the systems responsible of the delivery of those services

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and their operation management approach that will establish the efficiency level of the facility and the level of satisfaction of the users [2].

The completion of this accurate picture of the baseline scenario will facilitate the identification of deficiencies and improvement opportunities to be provided by the deployment of the Sporte2 system. Therefore, this analysis will influence the scope of the deployment in terms of affected activity areas, functional systems and the required functionalities (modules) [3]. It includes:

- Sport facility areas identification, functional requirements study and benchmarking. Performed activities will be analysed focussing on their associated services and functional requirements (heating, cooling, lighting, ventilation, DHW), as well as on the energy consumption and costs, if possible, disaggregated for each of the delivered services and normalized in relation to usage intensity (hours and people) and climatic conditions (heating and cooling degree days, etc.).
- Analysis of operation requirements, operation strategies and control rules of the functional systems of the facility that provide services and that consume energy, as well as the existing distributed generation systems: HVAC and domestic hot water generation, PV system, CHP plant, Solar production system, etc. They will be analysed, from the perspective of the adequacy of the selected technologies and technical solutions, operation approach and obsolescence.
- Facility management analysis in order to detect obsolete or inefficient energy strategies and control rules, inadequate or too static set points, obsolete control hardware and deficient integration of specific parts of the facility

The definition of the methodology includes the production of a list of deficiencies frequently found in sport facilities related to system control and management as well as the corresponding energy efficient strategies that should be implemented to overcome them. Some examples are shown in [*Table 1*]. This list was updated in the validation process by the implementation of the methodology in three pilot facilities. These check-lists are a valuable tool to support the implementation of the methodology for facility management analysis.

Deficiency	**Optimized energy efficient control strategy**
….	…
Too rigid set point temperatures for activity areas (heating cooling)	User comfort index based on the activity
Heating and cooling coils operating simultaneously	Optimize heating and cooling temperature deadband
Synchronization problems between different systems (AHU heating while fancoils cooling consequence of a wrong ventilation air temperature set point) during intermediate season	Optimize synchronization of mechanical ventilation air temperature to the operation regime (heating or cooling) of the activity areas

Natural ventilation systems not operating when beneficial (acting when it is not positive or not acting when it would be positive)	Resetting of conditions to trigger natural ventilation operation
Equipment permanently starting and stopping consequence of incorrect dead bands of set points	Reset deadbands
Water distribution to thermal loads without any demand	Optimize pumping group management (at least on/off, if possible apply variable control strategies)
Excessive production temperature and local cooling of the water at the demand points in order to avoid safety risks. (DHW)	Reset production/distribution temperature set point
…	…
Excessive outdoor air % when using dehumidifying heat pumps on swimming pools	Optimization of ventilation air to provide IAQ but maximize condensation on the heat pump (maximize energy recovery). Optimization of the set point values of the variables that affect and modulate the value of ventilation air flow rate
Excessive night cooling (undesirable heating demand on the first hours of the day)	Fine tuning of the set point values of the variables that trigger and set the schedule(start/stop) and intensity (air flow rate) of the free cooling mode
….	….

Table 1. Examples of deficiencies and energy efficient strategies to overcome them

Optimization scenarios definition

As a result of the baseline analysis process, all the potential improvement opportunities and the deficiencies that should be solved are identified. These conclusions are the basis to generate feasible and promising optimization scenarios in terms of their impact in energy savings, comfort improvement, user satisfaction level improvement and cost reduction [4] [5] [6].

The scenarios are produced by mapping the identified deficiencies and feasible energy efficient strategies with the corresponding activity areas of the facility [7]. Therefore, the scenarios are designed as a combination of different energy saving strategies implemented in specific activity areas and functional systems of the sports facilities [8]. The definition of the optimization scenario is done by the identification of potential energy optimization scenarios and their evaluation [9] [10]. The evaluation will be performed using the information collected about the energy consumption, users comfort and cost of operation of the whole facility and disaggregated by activity areas and functional systems, reflected on primary and secondary indicators: kWh/(m^2year) for heating, kWh/(user year) for swimming pool water heating, kWh/(m^2operation hours) for cooling, etc. The evaluation process will allow first the classification of the potential optimization scenarios for the facility and then, their selection for implementation. The criteria for the evaluation of the scenarios can be classified as:

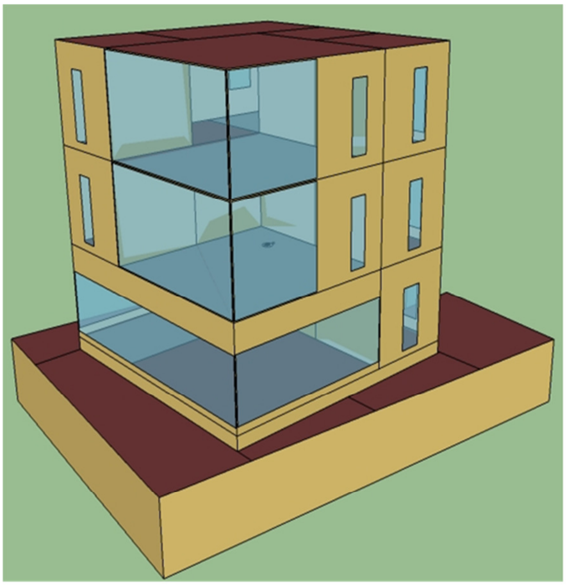
- Technical and economic feasibility of the scenario.

- Energy saving and cost reduction potential of the scenario.
- User satisfaction improvement potential (comfort and IAQ improvement).
- Priorities of the managers of the sport facility.

Scenarios Modelling and Simulation

Model development and simulation will consist on the modelling of the optimization scenarios, according to the developed modelling specification. It is a key part of the methodology necessary for deficiencies detection and assessment of improvement opportunities before the deployment of the system in the facility [11].

The modelling process will include the architectonic and constructive definition of the facility the characterization of the activity developed in the scenario rooms, the identification of the systems and equipment involved in the scenarios and the description of the desired operation criteria [*Figure 7*] to be included in the models [12] [13].



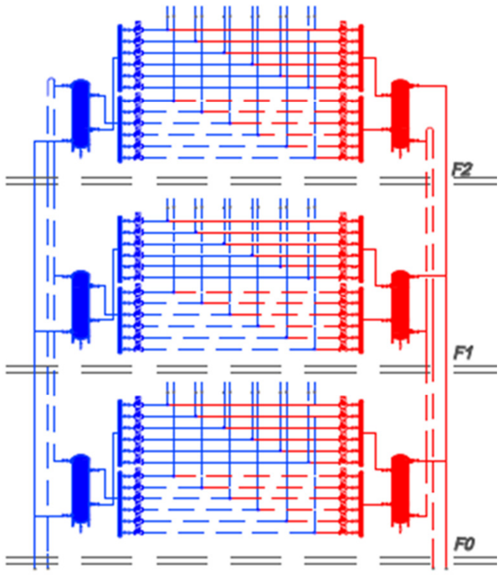


Figure 7 Heating and cooling water distribution system model

The generated model will be calibrated in an iterative simulation process in order to provide the maximum accuracy to the obtained results. Model calibration and model/scenario fine tuning will greatly contribute to the final definition of models. The calibration will consist on the fine tuning of key parameters of the model (occupancy patterns, internal gain patterns, system hysteresis and efficiency, infiltration level, etc.) in order to capture the actual behaviour of the scenarios to be optimized. When possible, the use of measured energy consumption values will play a significant role in this calibration process. Model calibration will also include the evaluation of all the relevant input and output variables to reach the optimization goal of each specific scenario: Climatic variables, indoor comfort variables, ventilation air flow rate values, supply air temperature values, solar plant production, CHP plant electricity and heat production, heating/cooling energy consumption, etc.

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Conclusions

The analysis of the baseline for deployment of BMS in sport and recreation buildings is of crucial importance because it will influence all the design decisions to be taken in the service deployment process and the final potential of the service in terms of costs reduction and user satisfaction improvement. The methodology enables the characterization of the activities and systems existing in the facilities, and the necessary process of deficiency detection and improvement opportunity proposal.

The conclusions provided by the baseline analysis are used to generate feasible and promising optimization scenarios to be implemented in the facility, as a combination of different energy saving strategies implemented in specific activity areas and functional systems of the sports facilities. The selection of the scenarios are performed according to their energy savings, cost reduction and user satisfaction improvement potential. Then, it is necessary to develop a detailed specification for each of the optimization scenarios including the identification of the involved systems and equipment and the definition of the control rules and set points to be used in the optimization process.

In order to capture the actual behaviour of the scenarios, the models are calibrated through the fine tuning of key parameters, and whenever possible, measured energy consumption values play a central role in the calibration process. During model definition the optimization scenarios and the models are iteratively fine-tuned, until the models can accurately reproduce the behaviour of the scenarios and provide high quality data for optimization process.

The final analysis is based on the results of the dynamic simulation of the optimization scenarios under different conditions that allow, not only the assessment for deficiency detection of current management and control process of the facility, but also the simulation of several alternatives for improvement.

The methodology has been validated in the global Sporte2 system validation process in the project. The system has been deployed for testing and validation in a two steps process. First, a prototype of the system has been deployed in a full scale building laboratory environment (Kubik by Tecnalia) for system integration and testing and then, the system has been installed in three full-scale pilots representative of the sector in Spain, Portugal and Italy.

The validation process has been useful to identify some new necessities to be covered by the methodology and improve it. It has been detected the convenience of generating preliminary lists of critical aspects to focus on facility management analysis and improvements to support the analysis. The mapping list of usual deficiencies and the corresponding energy efficient strategies have also been improved after the implementation of the methodology in the pilots. The necessity of reinforcing the calibration process of the simulation model by an iterative process has been confirmed during the validation process.

Acknowledgements

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Session 122:

Soft mobility and walkable neighborhoods. Are there any specific proposals for the dense city centers?

Chairperson:

Higueras, Esther

Profesor Titular UPM. Profesora de Postgrado UPM. Departamento de Urbanística y Ordenación del Territorio ETSAM UPM

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New urban landscapes of the mobility for the sustainable city

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Abstract: *Nowadays too many are the Mediterranean cities that have unsatisfactory structural setting and governance of public services in terms of mobility, naturalness, urban security. How do we deal with a overall redesign of these cities within an acceptable timeframe and with limited resources inevitably compared to the width and the correlation of the problems?*

In line with those guidelines take their place the preconditions and pathways tuned for the just concluded development of the research CityMob, The enhancement of the urban heritage through innovative models of sustainable mobility. The cities that present a suffered public mobility can now become experimental laboratories for the development of innovative models of sustainable urban mobility directed to the planning of interventions of quick realization at low costs, appropriate to encourage the use of public transportation rather than the private one.

Urban heritage, soft mobility, spaces of relationship, urban magnets

The CityMob experience

The main key- matter regarding a possibility to reconsider the structural setting and governance of public services and facilities in terms of mobility, naturalness, urban security, living of those cities which are deprived, it's that of s a total ridesign of these cities in satisfactory time and with inevitably limited resources. That's a common aspect in many urban areas of the Mediterranean, especially in metropolis with millions of people such as Cairo, Istanbul, Amman, that are suffering from bad urban mobility, from congestion and paralysis for the high number of vehicles with a high level of pollution. Such urban conditions, which are common in many Italian cities and are sometimes strictly related to people's cultural background, also depend on measures adopted in order to build new car parking areas where the cities are more congested, new roads or big shopping center parking areas, that are also included in the PUM (Mobility Urban Plans) and in planning documents. If Turin, Brescia and Parma stand out as sensitive "eco -car" cities, many other cities like Catanzaro and Reggio Calabria are at the bottom of the ranking, provided by the sixth report "Sustainable mobility in Italy: survey about 50 major cities", developed by Euromobility. It emerges a picture that requires a sharp turnaround through a vigorous plan of action in favor of cities that have neither park and ride, car and bike sharing system, bike paths, nor controlled traffic zones, and that are not provided with efficient public transport, but with unsustainable number of cars per square kilometer (qk) and high number of mortal accidents.

For those urban realities, exemplary models from the mobility point of view, some northern European cities to such as Oslo, Stockholm, Zurich, Helsinki, Vienna are to be considered as models, which have planned admirable outcome themes of urban eco- friendly, efficient public mobility, green infrastructure, all redesigned through rare sistematicity, congruence, foresight and ability to monitor the effects and consequent timely feedback.
Those are well-chosen urban conditions obtained from strict long-run incremental logics, which have been able to direct resources with continuity toward the mobility theme. Such methods cannot be obtained in medium-short time term, especially if we consider the current economic trends, in those cities that need quick solutions because they suffer from acute conditions of urban congestion. Actions can be suggested by the Interministerial Committee for Urban Policies in the document *Methods and contents for urban policies* as regards to *Priorities in the field of Urban Agenda*, presented by the Minister of Territorial Cohesion on March 20, 2013,in order to overcome fragmented sectorial government - security, mobility, urban heritage –through strategies for the development of urban areas. Certainly, the issue is not new, just think about consolidated examples of Colin Buchanan's studies, almost half a century ago, who faced the need to solve the problem of urban traffic, reconciling the demand for mobility with the need in maintaining a good environmental quality. So that, even under EU- pressure policies, from a more general urban sustainability policy (Aalborg Charter in 1994, Lisbon in 1996, Leipzig on sustainable european cities, 2007) to a more specific one on mobility, contained in "Libro Verde verso una nuova cultura della mobilità urbana 2007" - studies, researches and experiments have taken place with some success, especially where there was an awareness of not being able to face the problem, apart from the organization of urban space, but to search the solution through long-term strategies and especially in a logical system, just considering the urban vicissitudes of Copenhagen, Berlin, Paris, Amsterdam. The desire to enhance the value of urban heritage according to the principles of sustainable development has encouraged, in the management of land government, practices and tools for implementing interventions that are compatible with the environment. Among these, of particular interest is the one dealing with the transport sector. The latter, in fact, in terms of accessibility and urban mobility, is closely related to the enhancement of the urban heritage, but it fits into broader reflections about the city planning (both as a design of new settlements and renovation of existing ones), and in particular into the issues relating to the quality of urban life and sustainable urban development.

For this purpose, strategies of intervention in urban mobility field, in particular those of medium - long time term, should be based on the essential integration and coordination between transport planning, mobility and urban design, principals that could be summarized in the contents of the town planning, from specific projects dedicated to the infrastructural relational and settlement system. Strong request for actions to promote mobility, which is struggling to find shape and space on the national political program, might deserve quick answers, through appropriate integrated urban policies for redesigning the structure of urban mobility and its social, functional, structural and perceptual consequences. To obtain full livability for urban centers and opportunity for citizens to move about quickly and safely, it is

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necessary that the national, regional and local initiatives to environmentally-friendly mobility (economic, social, environmental, healthcare), should be integrated and coordinated, to be effective, and in line with European strategies. Moreover, the integration between urban design and mobility represents a new vision that combines research and innovation, also coherently with the Horizon 2020 program. Urban design, that is not interested in mobility, is static, as if it directs its interests to inanimate places and is not able to understand the direction that the main urban places, the magnets of the city, trigger with alternative fortune. The success of public spaces, meeting places, shopping streets, urban neighborhoods, is not always explainable only trough planning parameters; often hard managing and sometimes dynamics that difficult to be interpreted trigger; what is certain is that the measure of success depends on the ease of access points and on fluidity, frequency, pleasantness of the fitting mobility systems. In addition, the nature of the systems of mobility as networks, makes the conceptual integration between design and creation of urban eco- friendly networks extremely necessary. This integration is being experienced in certain cities with high interest, but it is struggling to find its own statute in large geographical areas.

Value of integration and co-ordinated supply of mobility

The requirement and pathways for the development of CityMob research, 2011-2013, are placed in line with these tendencies: the enhancement of the urban heritage through innovative pattern to sustainable mobility. The specific issues that research addresses are related to the identification of innovative approaches to sustainable mobility, identifiable in the broader definition of *soft mobility*, coherent with the settlement systems and urban system which is related to, so that to promote and encourage the use of local public transport.

An integrated system of public transport, private transport, pedestrian path, should provide frequent connections in the 24 hours and full coordination between the different modes of operation that does not allow systemic dissonance. That is to create a turnaround and increasing rates of public mobility perception and good urban areas quality. Strongly mode of urban transport condition influences the inefficiencies of urban transport as if the city does not offer useful railroad links from nearby towns and major cities for commuters, it will inevitably fold back on private bus network and of private vehicles as it has happened in Calabria for many years. That can't be a choice but a forced act, when, in fact, the use of public transport irrationally expands the trip time and forces to "dead time". Much can and should be done at regional level and for the Metropolitan Area of the Strait, to be connected and to connect cities and mother-city to the surrounding. As long as these inefficiencies persist and there are no transport facilities, which start from the main gates of the city, or of suitable park, there won't be sustainable traffic conditions. The intensive links, extended over the 24 hours from the entrance gates of the city, such as airports, ports, railway stations and major motorway links, with the main city magnets, in terms of advanced services, health care, cultural, commercial, accommodation, restorative (services), but also squares, gardens, parks and promenades, could solve most of the problems related to mobility and offer a viable and appropriate alternative in the use of vehicles. If the frequency and extent of daytime and nighttime transport depend on factors and organizational resources to be used in the public mobility, the certainty of time ride can be ensured only by means of using dedicated site. For mid - small towns it is not worth building an expensive underground, but it may make sense to change the concept of network, at least on the surface. Radial cities like Paris, Vienna, London, Milan, extend their networks more and more in terms of lines and stations with the purpose of creating triangulations of about 300 meters on each side that serve every part of the city, that's to say a triple choice, with respect to more convenient station to be reached (as far as the distance and the line changes and the destination needed to reach, are concerned). Rome, also radially extended, but with large areas of the city center not served by the underground, compensates this limits with surface public transport with - trams, buses and shuttles, as well as a wide range of taxi services-. Naples, with four cable cars and two metro lines- the historical one has been proved excellent, thanks to the realization of stations of art, so much so that it has become worth to be visited - offers a complete network of railway transport and a bus system together with a central car park system made from the recovery of degraded areas of the underground "Bourbon's tunnel". Morelli parking is a clear exsample. Genoa like Naples, with an arc due its coastline -an amphitheater overlooking the sea- has built its light rail - seven kilometers, eight stations that serve the main cultural and commercial magnets of city well - connecting the center with the district of Certosa to north - west, an elevator system in Castelletto and Montegalletto and Sant'Anna e Zecca - Righi funiculars. Moreover just started the rack railway for Granarolo. In absence of metropolitan underground or surface networks, the Curitiba - Bogota model teaches that it is possible to design and implement a system of public transport links on the road with the required safety for passengers at stops. Think of the Metrobus - Rapid Bus Transit system conceived in Curitiba, Brazil. That was taken as an example followed by other land American countries, and in particular in Latin America with the Transmilenio in Bogota, Colombia, or the building of the Metrobus in Mexico City that incorporates the already extensive underground network. Discontinuity that encourages creative sustainable lifestyles, just think that after Amsterdam and Copenhagen, Bogotá and Curitiba are the cities that use the bicycle as means of transport most. This is because it makes no sense to propose a redefinition of urban space if it is not preceded by possible measures aimed at sustainable transport and coherent policies for sustainable mobility. Therefore great measures and incentives are necessary in order to support the use of public transport starting from the protection and safety of dedicated site, so as to increase speed and regularity, accompanied by an increase in racing and extended working hour service lines, buses and undergrounds at night times. The fact remains that other countries will continue to invest in ambitious projects: the main Spanish cities are working towards the development of underground transport, resulting, in contrast with elsewhere in Europe, significant increases in the percentage rate of pedestrian mobility, also due to interventions in the field of quality and characterisation of urban spaces.

The conditions for the success of eco- friendly mobility

An efficient system of public transport is an essential condition, necessary but not sufficient, that the eco- friendly mobility can take roots, just because you choose to use the chain "public trasportation- moving pedestrian" and any movement cycling paths. The concept of triangulation of the surface or underground, gives chance to reach each node served by the connective network - also made up well equipped bus stops and strategically placed at the main squares and collective service, cultural, health, hospitality and recreation areas - the target destination that can be represented by urban magnets or residential areas with a fifteen minute distance, covering a distance of a smooth mile, less with an incline or slope. The integration of supply with tramways, "ectometrics systems", buses with dedicated lanes, urban areas shuttles, increases the percentage of residents who live less than three hundred meters away from an underground public service, such as the city of Hamburg. The reason why you continue to insist on proposing a model type of environmentally-friendly mobility that, even after years of trying is hardly changes habits, the Italian situation that "highest indices motorization in the world estimated, continues to grow". Despite the presence of many art cities with urban settlement that are not just built for cars but for walking, in terms of physical well-being but also for the overall awareness of pleasure to participate with the people's presence in the local scene to the changing expressions of urban landscapes.

Cities for Walking and Health is a new project created to promote healthy lifestyles through "the rise of the culture of attention to proper health and sensitivity towards preventive actions, simple to implement but very effective", ... "to the improving health by carrying out motor activity such as walking". Now the project involves 30 cities and territories, which deserve "health passport" because they own trails designed for motor, useful for healthy prevention. Some regions have focused on nature trails, others have invested on urban roads, urban fit walking, involving the centers of Turin, Brescia, Trieste, Florence, Matera, Lecce that propose a "city on a human scale where walking habit is a distinctive symbol of civilization and progress". Since this model might be applied three specific conditions should be considered: first, there must be a healthy separation of vehicular traffic from pedestrians and cyclists or at least there should be created appropriate measures for coexistence; secondly, a city should make easy, even with the aid of hectometers systems, the practicability of the traits in prohibitive slopes or however tiring of urban centers by orographic complex profile; thirdly, that is eventually secured an overall urban quality in terms of climate comfort of routes (system of shading, roofing, porches), presence of interspersed repaired seats a right distance and tasteful urban decor and exciting variety of flooring and anything that contributes to characterize a city. The main European cities offer mature solutions and experienced of vehicle - pedestrian coexistence, such as those of zones 30, of the *traffic calming* or *wonerf* (shared area in the Dutch language, that is a street where pedestrians and cyclists have priority and where vehicles are forced to proceed to a crawl, equivalent to the *zone de rencontre* or *living street*) for the presence of speed bumps, raised crossings, raised central islands with wide sidewalks and green space or, more recently in connection coplanar. Actions for discouraging private circulation and controlled traffic measures (ZTL, paid parking in the city center) which are perhaps to be preferred to the entry taxation or the creation of exclusively pedestrian islands. In the “compact city” or in the historic town, the pedestrian islands may offer new opportunities for the revitalization and protection of historical and artistic heritage, with positive impacts on tourism activities and economic trade. For example, consider the experience of the pedestrian street “San Lorenzo” in Genoa, ranging from the old port to the Ducal Palace, stone-paved restored together with the restoration to facades of the buildings during the G8 Summit in 2001, which introduced the what has been called a “virtuous cycle of excellent pedestrianization” acting for the success of a change of mentality. It is clear that even in terms of allocation of space, in relation to different modes, each detail may contribute to the smooth functioning of mobility and full accessibility, diversified for different urban element in order to indicate directions and drive paths, can help create a design of explicit soil, suitable to delineate clearly the vehicular, pedestrian and cycling path and their intersections. The objective design of increasing the area of the isochrones, an impediment to be answered, concerns the urban trails in steep slopes. Overcoming city inequalities route, can determine the success of soft mobility in relation to the entire connective tissue and sometimes can combine urban parts morphologically unrelated.

Mountain lifts, escalators, *tapis roulant*, urban elevators, *people mover* have connected walkways at different levels or with excessive slopes, making possible the diffusion of environmentally friendly mobility in a wider radius of the city. The historic funicular in Naples, with the current 16 stations, integrated with the network of underground, funicular of Genoa, Todi, Orvieto, Catanzaro offer a convenient, quick and democratic connection, as well as the Mimetrò that connects the area of Pian di Massiano with the historic center of Perugia, the Venice’s *people mover*, which connects the maritime station of Ankle Boots to Piazzale Roma and Milan that connects the *San Raffaele* Hospital to the underground. What about Genoa if not provided with eleven elevators built in a century? The first built in the 1910s, in the so called “short century”, the second to last in the 1970s, and the last one, between Via Centurione and Via Bari, opened at the end of 2010, in addition to the tilted elevator of Quezzi still in progress. Also the funiculars in Genoa let a better use of valuable urban space "disputed to the sea and to the mountains". There are then "service" elevators as in Naples, Acton, Chiaia and Sanità, or as those in Siena, Spoleto, Gubbio and Narni that link the town centers from the city gates at lower altitudes.There are also elevators that are "artworks" as the glass elevator built in Colle Val d'Elsa with the expert advice of Jean Nouvel, which connects the *Baluardo* to the lower part of the city, overcoming a height difference of 40 meters in a vertical tunnel that uses glass walls that recall the crystal industry, symbol of the city. Perugia's escalators, started in the 1980s in the Rocca Paolina, provide easy access to the upper part of the center. The historical center of Potenza is connected with the downstream neighborhoods by a system of 1.3 km escalators, built in 1994, which now holds a "European record". It seems to be "slightly lower than those of Tokyo, first in the world with 1.5 km". Extensions this, that go well beyond the already experienced projects, if you think that public transport is defined as "automatic driven people mover" from "hectometer", one tenth of the kilometer, because it useful, even for the high cost of construction and maintenance, to be used on short routes. The advertising of soft mobility requires a sensible planning quality to interpret the dimensions and levels of the city in flat surface, ramps and suitable fittings to create the continuity that makes it easy coplanar paths. The widespread urban quality, with trees, hedges, flower beds well-groomed, shading systems, seating, good lighting, walkways or patios, urban tunnels, squares, plazas, urban outdoor lounges, makes the city cozy and encourages outdoor living, meeting, exchange and conviviality. The *en plein air* art adds value and amazement to promenade, making urban spaces with uncertain boundaries, such as Rotterdam's river banks, a city with a strong port connotation, an open gallery exhibition.

Finally, we can close with a certainty that an efficient and integrated mobility may be the main strength of urban regeneration policies and that the increase in value of entire urban segments could be achieved only through public actions of increase mobility. These should aimed at achieving a better accessibility, at strengthening urban centrality and polarity, at the redevelopment of public open space, at using of interstitial spaces, all elements of an experiment that can help contribute the vitality of a city ready to competitive with as far as the quality targets and sustainable development are concerned.

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Soft mobility in the urban areas. The case study of Reggio Calabria

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Abstract: *The proposal of a sustainable mobility project for the use of assets requires evaluations regarding the balances that regulate the territory and its functions that necessarily involve the introduction of the concept of quality. The efficiency of public transport and collective services, the well-kept historical center, the suburbs integrated and connected with the entire city, a strong morphological and cultural identity of the settlement, are, on the whole, the results that a careful project of the territory should be able to achieve. This contribution intends to deal with the issue of public mobility and accessibility in a view of territorial development linked to the use of the urban area asset of Reggio Calabria.*

Strategic planning, accessibility, urban heritage, soft mobility

Introduction

Today, in a context of strong international competition and following a new re-orientation of the demand, the urban asset present in the cities is increasingly becoming a driving force for the economic and local cultural development in a awareness in which it aggregates and integrates resources and services within areas characterized by strong territorial and recognizable identities, in overcoming the fragmentation of the offer. In this context, Reggio Calabria, as well as other European cities, in programming the incentives offered by EU policies towards the development aimed at enhancing the cultural and landscape asset, is ever more spreading the use of new strategies for a local development to integrate the cultural sector and those connected to it, such as tourism, pursued through a territorial specialization and urban policies where the parts of the city become the privileged place for the establishment of cultural facilities or logistics. This arises from the need to put in a network the high concentration of cultural and environmental resources of value with the quality and

the concentration of cultural and tourist services, dedicated to users.

However, the first projects, except for the exemplar case of Bologna, of culture of sustainable mobility diffusion, yet they do not create a genuine integration in the local development policies and concern, in general, interventions aimed at reducing pollution or at the regulation of city center access to reduce the burden of traffic. It deals with interventions different from each other and hardly connected in a network point of view, but that have contributed to the awareness of these forms of organization of the territory, attracting considerable interest and attention from the economic, social and territorial institutions towards the prospects of a possible and significant capacity for self-organization of the local contexts.

Today, under the pressure of territory government tools innovative and thanks to a different cultural approach, we are in the condition in which it is possible the recovery and restoration of the territory through the identification of strategies and projects that are able to introduce quality of connective space and cultural kind of services based mainly on promoting the connections and the fruition of this asset. The Regional Addresses (Framework Program Agreement Emergencies Urban and Territorial Intervention Program of the Department of Planning and Government of the Territory of the Calabria Region) ask to abandon the " unsustainable " intervention models and to replace them with " appropriate measures to the safeguard and enhancement of the resources and landscape values still intact along the Calabrian coast, which require an articulated plan of actions for the restructuring and retraining and reorganization of the physiognomy of the coastal system as a whole, capable of understanding the continuity of naturalness, recovery and reorganization of the settlements. "

The importance of the theme is also witnessed by numerous initiatives to promote sustainable mobility linked to the urban asset as the recently MUSA project, coordinated by Isfort and developed with Cittalia, Cles and Anci ComuniCare promoted as part of the PON National Governance and System Actions (ESF Ob. Axis Convergence 2007-2013 and Institutional Capacity Ob. Specific 5.1) by the Presidency of the Council of Ministers - Civil Service Department (DPF) - Office of Personnel Training (PA UFPPA). Reggio Calabria is one of eight pilot Administrations part of the project directed to the municipal Administrations on the theme " Sustainable Urban Mobility and Cultural Attractors " with the intention of encouraging the development of policies and innovative interventions in key of economical, social and environmental sustainability in urban areas of the Convergence Objective. The main objective is to provide the means to strengthen its ability to govern the problems of urban mobility, with a view to greater sustainability and to identify and test innovative models and tools for sustainable territorial planning interventions.

In addition, the MUSA aims to strengthen the capacity building of the public administration in the field of urban mobility and cultural attractions, and start a "subsidiary" building of the reference tools through the involvement of all local actors involved (administrators, institutional representatives, stakeholders). The developments of this project could take a strategic importance for our region in view of the opportunities that are offered to experience

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a new methodology, able to engage directly with local forces to address the issue of cultural attractors related to sustainable mobility.

The basic idea is to support the construction of a network of urban heritage in mobility systems that are able to undo the imbalances in terms of accessibility / usability, promotion and enhancement. It is now time that city in the idea that all human functions and activities becomes necessary to improve public transport and urban mobility. The center is above the center of culture and tourism in the city, with its fine buildings, monuments, archeology, as well as the rediscovery of the sea thanks to the development of the waterfront. In fact, the element can be able to connect and operate otherwise uneven spaces can be represented exactly by this, or rather from the urban promenade, based on the historical pattern of the promenade, the park - promenade that runs along a linear space, where it is privileged and emphasized the themes of the course and going. The redesign, with a foreshadowing of more or less radical changes made through the construction of new space or connections (routes and itineraries for leisure time, with walking and cycling routes) that become elements of connection between the parts of the city, tends to attribute or return conditions of higher urban quality, in accordance with the principles of environmental sustainability, as well as a strong influence on balanced and spatial dislocation of functions, also on the processes of creation of new places, new public spaces that they can convey meanings of belonging and identity form a collective.

These new spaces must be in line with the new cultural consciousness expressed by the territory and aimed at cultural development through the creation of eco-museums, to nature trails, areas of experimental teaching, etc ..., which could allow the development of strategies for the promotion of the "heritage urban "in view of a general process of development, in a balance between economic competitiveness and environmental compatibility, in which the binding of the inhabitants with their resources plays a key role.

The promenade can be considered a true unified strategy of the territory aimed at ensuring the connection between urban centers, the system of the beaches and public spaces, because the urban promenade thus understood physically as well as visually connects the existing territorial signs and puts in the network cultural historical presences with all the other human activities there.

The recent projects of urban mobility

The possibility of integrating a new system of mobility to the enhancement of the urban asset of Reggio Calabria. This necessity comes from an implicit need, which is to enhance and to promote a cultural and social use for the resources present in the territory and flows from new instances of a quality tourism that in Reggio Calabria, as well as in many other southern cities, require a careful search of new cultural desires with new destinations, which led to the discovery of products more rich of meaning and content, of authenticity, of identity.

The ambit in which Reggio stands, represent the terminal head of the Italian peninsula as well as the most studied territorial area in recent decades for the actual and potential relations with the Sicilian side. This condition has strongly influenced the urban area, populated by circa 180,000 inhabitants, which has a high concentration of functions with the presence of the University, the Conservatory, the Academy of Fine Arts and the University for Foreigners, the hospital poles, the Region and Province office, the airport, the port, the sports facilities and numerous administrative, production and sales activities of regional breath.

Reggio can be defined as an ongoing project on mobility issues because in recent years there have been many interventions but especially designs that involved, directly or indirectly, aspects of movement, traffic and navigation mode. Another important aspect is the fact that Reggio has been using for a while "innovative" figures in the field of mobility: Mobility Business and Area Manager[1]. The first figure has functions of collecting information for the preparation of Travel Plans, preparation, monitoring and updating the home work Plans Moving[2], identification of projects to be proposed for the mobility of City employees. The second deals with the census of companies and organizations involved in mobility management, the connection actions with other services, local authorities and companies with expertise in mobility, coordination, monitoring and guide of the activities of the Corporate Mobility Manager, identification and coordination of projects related to the corporate mobility and movement of a systematic nature.

In reality, the sector planning has created, over time, a multitude of projects and conditions to create a turnaround. Since the creation in 1995 of the new waterfront Falcomatà, it started however to move a slow but steady process of reorganization, aimed to improve the image, but also and above all the usability and accessibility to public places of the city.

The specific sector planning has focused on the development of different scenarios, one of the first is the Urban Traffic Plan (PGTU) that regards the measurements of the traffic flow, accidents analysis, public transportation, analysis, noise and air pollution. It has also worked to realize simulation models, of a computerized street land register and a road regulation and the modeling of alternative scenarios.

The second is the strategic plan for 2007-2013, prepared by the method of strategic planning, and is articulated into four actions, which in turn are articulated into fourteen specific objectives and a numerous operational objectives: Reggio node of relationships in the Mediterranean; Reggio competitive and attractive city; Reggio city to live, and Reggio united city. The specific objectives converge on employment growth, pursuing the goal of the Lisbon Strategy, and on the projection of a community that seeks its own space and its own recognition in the Mediterranean and international scenery.

The Agreement Program, construction of a new public transport system integrated area of Reggio Calabria and the Strategic Plan for sustainable mobility represent a turning point not only cultural but also realization. In fact, the agreement, which provided the creation of a new integrated system of metropolitan public transport, with the modernization of the existing rail system, has allowed the creation of the people mover system. This system, in the Strategic Plan for sustainable mobility, is replicated with a project that involves another treadmill, so to easily reach from the Hospitals the Lido station with a pedestrian path on level ground and secure. The Plan was originally planned (2009) from the signing of a Understanding Memorandum for the use of funds allocated to the upgrading of transportation systems useful to reorganize urban mobility and accessibility of neighboring municipalities and encourage the development of a highly integrated metropolitan area.

The provided actions concerned: the strengthening of the coastal railways service, the connection of the central urban tissue with the main poles of attraction, located along the axis perpendicular to the coast (Hospitals, University Campus, Head Office, New Court, etc..) Enhancement of maritime links with the bank of Messina and the creation of a platform for the control of public transport and private traffic. The plan envisioned a system that would produce significant regional effects from Villa S. Giovanni to Melito Porto Salvo.

Of great importance is also the Urban Mobility Plan (PUM). "The PUM represent a planning document of mobility aimed to the development and enhancement of "Reggio Calabria Mediterranean city" projected, in the area of the Strait as a whole economic, cultural and social system, and as a node of excellence of the regional, national and European infrastructure system[3].

The Urban Mobility Plan integrates the Strategic Plan of the city of Reggio Calabria and defines a set of priority actions in the field of mobility and its implications.

The reference scenarios of the drafting plan include existing infrastructure, those with work in progress, those planned with full financial coverage, the organizational and management actions for the optimization of the transportation system and for each reference scenario, with appropriate forecasting and simulation models, will be analyzed the criticality of the transportation system. The project scenarios will be obtained by adding to the reference scenarios the new infrastructural and technological interventions as well as the organizational and management ones for the optimization of the transportation system that will provide the PMU.

So, with this tool, the Administration also intends to follow up the projects previously expressed by the plans drawn up with the construction of multi-storey car parks, three new treadmills, new railway stations, two tram lines as well as other environmentally friendly design interventions PUM. The project will be based on the enhancement of pedestrians and, therefore, a fast and efficient transportation system made up of public means, for a city that can increasingly be on a human scale, as well as sustainable and livable.

The interventions to be completed are the creation of three other Treadmill (Stazione Lido up to the United Hospitals, University Town and connecting the areas of Engineering, Architecture and Agriculture Faculty), a train station nearby Via Giudecca, at the height of the treadmill, multi-storey car parks exchange, a series of interventions to improve the traffic flow related to the railway line (all level crossings in urban area will disappear, allowing a better traffic flow and a better use of the coast and sea in the south area of the city), an important intervention linked to the project of city waterfront (to put underground the Central station) and two systems of sustainable mobility and environmentally friendly in a reserved and protected venue.

The data shown on the report of Euromobility 2012[4] on the main 50 Italian cities, which analyzes in detail the state of the main indicators of urban mobility, describes the city of the Strait as the most unaffordable city sample (48 out of 50). Reggio, with its population density of 790.2 inhabitants / km² has an index of motorization in line with the Italian average (60.77 × Veh/100 Ab) with a vehicular density of approximately 500 Veh / sq km. The only quality that emerges from this table is an index of accident lower than the national average, while the death rate is higher. With regard to the limited traffic zone (1 sqm / inhab. Pedestrian areas), paid parking (22 stalls stops for 1,000 cars circulating), interchange parks and cycle paths always maintain itself in the bottom places of the rankings. Only recently a small service of bike sharing has started the construction of a bike path already heavily discussed, while car sharing is yet all to experiment.

The Waterfront and the south urban Linear Park. One of the projects that more than others gave international exposure to the city was, without doubt, the project of the new configuration of Reggio Calabria Waterfront. Among the many implications from the standpoint of urban mobility, the planned arrangement of the port area, which is still seen as a " other" space not in harmony with the city it would instead become whole with the urban organization of the waterfront. The project, in its organicity, provides numerous interventions all autonomous in a planning and financial sense. A first project, subject of an international contest of ideas launched by the Public Administration and awarded to the architect Zaha Hadid provides for the redevelopment and re-conversion of the coastal front for touristic activities, directional, tertiary, handcraft, commercial, with two symbol buildings: the Museum of the Mediterranean and the multifunctional Centre. Inside the museum are provided galleries, offices, archives and library, restoration workshops, an aquarium, dining centers and a communication area. The multifunctional center planned as a station for the fast connection shuttles via sea, will allow to get urban continuity with the city, through a pedestrian underpass that will connect the railway station with the town park. Are provided, also, an auditorium and a large covered square.

Another project which the Administration has adopted and made in part is the South urban linear Park[5] that should be seen as the natural extension of the Waterfront affecting the area between the mouths of the rivers Calopinace and S. Agata. The purpose of the project is to redefine the relationship city - sea, making the area fully accessible and connect it longitudinally with the city; to provide the place with accommodation facilities that would determinate the improvement of the quality of life.

The whole system is developed on a main carriage able system that has its origin and destination in four targets: the river Calopinace, the structure of the Circolo Pescatori intended to accommodate social activities and leisure facilities as well as for boats towage and mooring, The Officine Omeca and the river Sant'Agata. In one of the target, in the vicinity of the Officine Omeca, it opens a square where a “idroscultura” by the artist Diego Attilio Mario Raco called “Crescendo” is found, inspired by “La città che sale” of Reggio’s futurist artist Umberto Boccioni.

First Considerations

The proposal for a sustainable mobility project for the use of urban heritage in the territory of Reggio requires evaluations of balances that govern the city and its functions that necessarily involve the introduction of the concept of quality[6]. On these topics has been carried out the research: "The urban heritage through innovative models of sustainable urban mobility - CITYMOB" selected and funded by the Calabria region in the 'sphere of the public notice "for the funding of research projects in the field of sciences human, social and economic "(LR 22 September 1998, No. 10, Art. 37-quarter). Research Manager: Prof. Concetta Fallanca.

The efficiency of public transport and utilities, the well-kept historical center, outlying areas integrated with and connected to the entire city, a distinct morphological and cultural identity of the settlement, are, on the whole, the results that a careful plan to sustainability issues should be able to achieve.

It could be from the exploitation of parts “emerging” in the city to get a re-assignment identity of the areas that do not have recognizable features. The culture of the place and the quality of urban life should be understood as a reference to “key” to every human activity, to be taken as guidelines that can combine all the evolutions of the “big choices” for the area.

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Construction Risks of the Green Building Projects in Indonesia

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Abstract: *Since the last five years, the development of green buildings in Indonesia's big cities have been promising. In order to achieve the green building's objectives, one of the important project management processes that should be taken care of by the owners and contractors is to manage the risks associated with the project. The objective of the research was to identify the construction risks associated with the green buildings projects, considering the green building industry in Indonesia is still considered as emerging. By comparing the construction project risks associated with traditional building projects and the risks gathered from the interviews, the additional and the fewer risks associated with green building construction projects were identified. Furthermore, the research also found that the risks allocation for green building construction projects should be accommodated in the contracts between the owners and the contractors to enable the achievement of the green buildings' objectives.*

Construction project, contract, risk, green building

Introduction

Developments of green buildings in Indonesia's big cities have been promising in the last 5 years. The Indonesian government has been preparing some needed regulations related on the implementation of green buildings since then. The Indonesian Ministry of Public Works has been developing a standard of green specifications and also rating tools for designing, constructing, and operating green governments' buildings that will be introduced to central and local governments. In fact, starting year 2012, in the city of Jakarta, as the capital city, green building certification is a mandatory for new as well as existing buildings based on a Governor Decree. Even though the requirement to adopt green building concept in Jakarta is considered mandatory, it is a minimum level of green specifications that are achievable and processed as part of getting building permits for new buildings and operation permits for existing buildings.

One of other prominent movements in green building in Indonesia is the establishment of Green Building Council Indonesia (GBCI) in 2008 (Abduh et. al., 2012). Until now, there are more than 120 corporate members joined this organization, 3 new green building projects and 3 existing buildings that all had received platinum level of certification, and there are more than 19 green building projects registered to be assessed. The assessment system that is published by the GBCI is called Greenship rating tools which consists of three rating tools: for new buildings, for existing buildings, and for interior spaces.

Some large contractors, as the main subjects in the construction field, had shown their awareness and stewardships to the environment by declaring themselves as green contractors.

They have implemented reduce, reuse and recycle (3R) principles, as well as the reducing the use of energy in their construction projects. International certifications for environment management (ISO 14000s) have been their marketing weapons besides the certification of health and safety management from OHSAS nowadays. The practices of reducing the use of papers, catering waste, the use of air conditioning, the use of water and electricity has been their day to day operation in their project sites. Moreover, they tried to introduce their innovations in transportation for project's labors, the use of alternative materials that are environmental friendlier (Abduh et. al., 2012).

Yet, recent studies on the effectiveness of the green building implementations have shown the need of more holistic approach in delivering the green buildings by the owners, as well as the contractors, including the importance of constructors in delivering the green specifications as designed by the owners through the professional designers (Abduh and Imran, 2013). In order to achieve the green building's objectives, one of the important project management processes that should be taken care of by the owners and contractors is to manage the risks associated with the project. However, very few references and lessons learned regarding the risks associated with green building construction projects available to be used by both parties in delivering the green buildings in Indonesia.

Risk Associated with Green Buildings

Concerns on the risks that may emerge associated with green buildings have evolved as the introduction of the green building movements was enthusiastically responded by the owners of buildings. Several studies have identified the risks that may emerge associated with the implementation of green buildings with different level of maturity of the construction supply chains to support the green building projects.

Marsh (2009) has identified the top risk categories associated with green building projects in the LEED environment, i.e., financial, standard of care, performance, consultants and subcontractors, and regulatory. From this study, the financial risks relating to green buildings was the greatest area of concern; the additional costs associated with the design, construction, operation and maintenance of the green buildings may be too costly for the parties involved in the project, and then affect their capacities in completing the projects properly.

Odom et.al. (2008) argued that the greatest risk to the green building project is not the increased costs associated with green buildings, but it is more likely green buildings that don't perform as expected and their failures. Therefore, there is an increase of legal liability risk for designers and contractors if the buildings could not meet the specified green building certification requirements. Additional contract provisions and warranties put by the owners to the green building's contract could lead to an increased potential liability since the performance of new products and technologies used for green buildings might be developed quickly but not properly tested. This risk will be higher if the green building specification developed for a particular condition and geography was adopted to others without any precautions; such as different climate and availability of resources.

Moreover, since the technologies and practices to implement green buildings were considered relatively new, the construction supply chains, i.e., consultants, contractors, sub-contractors, and supplier, are not fully ready and experienced to successfully deliver the green buildings specification required in a green building specification. Trigos (2007) revealed some notable problems faced by UK construction industry in the area of green construction supply chains that were lack of human resources, short-term planning, limited access to information and expertise, and low demands from owners and government. Ofori (2000) also mentioned the same conclusion for Singapore with an emphasis in that the readiness of its supply chains was the key for Singaporean construction industry in delivering green value to the community. This condition of construction supply chains in supporting the achievement of green specification for green buildings will definitely expose additional risks to the projects.

This could also be the case found in Indonesia since its green construction supply chains is still considered immature and the green building movement is still in an emerging phase. Moreover, it was found also that the contract documents of the already built green buildings in Indonesia only emphasized on green specifications, while other possible additional risks associated with the more demanding requirements were not adequately addressed (Abduh, 2014).

Research Objective and Methodology

The objective of the research was to identify the construction risks associated with the green buildings projects, considering the green building industry in Indonesia is still considered as emerging. The research methodology selected for this research comprised a literature review, an interview guided by a questionnaire to the construction industry practitioners, and a qualitative analysis of the survey data.

Interviews to four contractors that had built four certified green buildings and two owners of the green buildings were used as the methodology for this research to discover the risks they have experienced during the construction of their green buildings. By comparing the construction project risks associated with traditional building projects and the risks gathered from the interviews, the additional and the fewer risks associated with green building construction projects were identified.

A list of construction project risk factors, consisting 57 risk factors in total, were identified from literatures and Indonesian construction practices that associated with traditional building projects, and then categorized into four groups of risks, i.e., material and equipment (10 risk factors), labor (9 risk factors), contractual (6 risk factors), implementation (19 risk factors), and management (11 risk factors). The material and equipment risk consists of risk factors that would emerge due to availability, cost, capacity, capability, delivery and operation of material and equipment to conform to the required green specifications. The labor risk factors are related to competency, wages, productivity, and behavior of construction labor to support the achievement of green value of the building project. The contractual risk covers risk factors that are related to coverage and unambiguousness of contract clauses, perceptions on the

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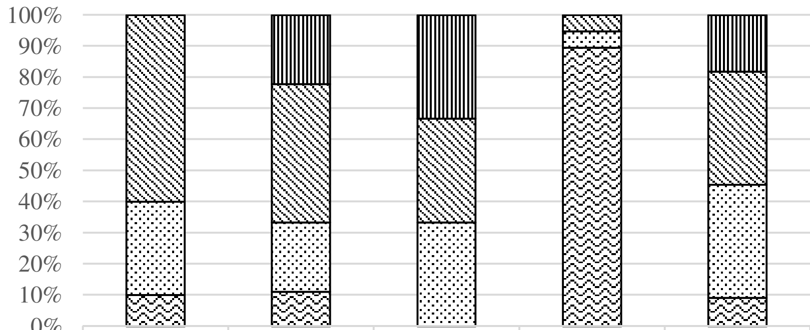
contract, payment, performance, and dispute between parties. The implementation risk is related to effects of construction operations to the environment, quality of production, schedule, and productivity of the operations. While the management risk consists of risk factors related to planning, designing, organizing and executing the construction project.

Those identified risk factors were then used in a questionnaire to be assessed by the respondents whether their risks will be reduced or increased in a green building project compared to a traditional building project. Moreover, the questionnaire also asked the respondents to identify any additional and omitted risk factors due to more demanding specification of green building projects.

Research Findings

Based on the interviews with two owners of two green buildings, Figure 1 presents the percentage of project risk factors that would have increased, reduced, and no change magnitude of risk, as well as the percentage of risk factors that would be omitted due to new more-demanding green specifications for the green buildings. While Figure 2 depicts the aggregated percentages of four contractors' perceptions to the same questions.



	Material and Equipment	Labor	Contractual	Implementati on	Management
Ommitted	0,0%	22,2%	33,3%	0,0%	18,2%
Reduced	60,0%	44,4%	33,3%	5,3%	36,4%
Increased	30,0%	22,2%	33,3%	5,3%	36,4%
No Change	10,0%	11,1%	0,0%	89,5%	9,1%

Figure 1: Owners' perception on risk associated with green building project

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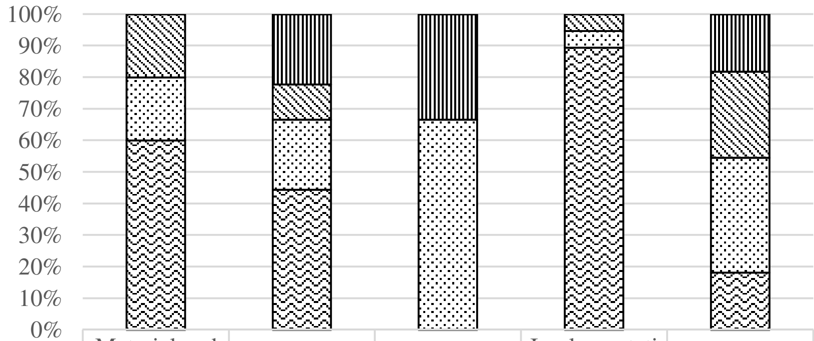

	Material and Equipment	Labor	Contractual	Implementati on	Management
Ommitted	0,0%	22,2%	33,3%	0,0%	18,2%
Reduced	20,0%	11,1%	0,0%	5,3%	27,3%
Increased	20,0%	22,2%	66,7%	5,3%	36,4%
No Change	60,0%	44,4%	0,0%	89,5%	18,2%

Figure 2: Contractors' perception on risk associated with green building project

Moreover, Figure 3 shows the percentages of risk factors that gained different perception between the owners and the contractors. It can be seen that the risk factors related to the material and equipment (50%), labor (44.4%), and contractual (33.3%) are considered to have conflicting opinions between the owners and the contractors.

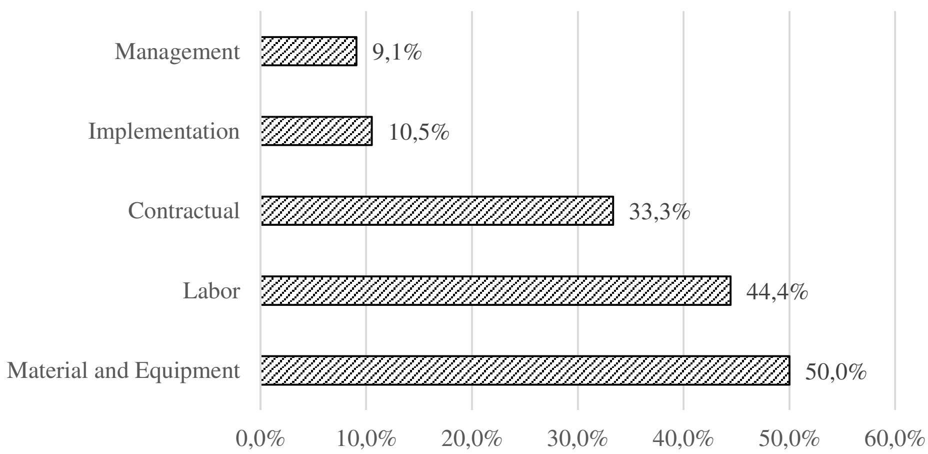

Figure 3: Percentage of risk factors that gained different perception between owners and contractors

The research also identified additional risk factors that would emerge and should be allocated to the owners and the contractors or shared by both parties (see Table 1).

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Table 1: Additional risk factors of green building projects

No.	Risk Factors	Risk Category	Allocation
1	Green product	Material and Equipment	Owner
2	Green equipment	Material and Equipment	Contractor
3	Health and comfort of project site and surroundings	Implementation	Contractor
4	Training for labor	Labor	Contractor
5	Contract revision	Contractual	Owner
6	Nature protection	Implementation	Shared
7	Water consumption reduction	Implementation	Shared
8	Green Behavior	Management	Contractor

Discussion

In Figure 3, it is shown that there is only small difference perceptions between the owners' and contractors' on management related risks (9.1% or one risk factor). The difference is related to the risk of inadequate project control and coordination. The owners thought that this risk would be reduced with the more demanding specification of green building, while the contractors argued that the risk is still the same. In this case, the owners assumed that the contractors would mitigate this kind of risk by providing more competent personnel. Moreover, in this management risk category, there are 18.2% or two risk factors that could be omitted, i.e., incompetent personnel in planning, and low discipline management, due to more expectation to have more competent personnel in the project. The increased risks are related to estimating, scheduling, change order, and dispute. Even though the risks related to management are generated from the more demanding and complex project, it seems that the risks are still considered as the contractors' risks by the owners.

It is interesting to see that the owners and contractors thought that there is only small changes in project risks on the implementation risk category. Both thought that the implementation process of green buildings were considered almost the same as the implementation of traditional buildings. This shows that both parties' understandings of green building only on green specification, and forgetting about how the construction process could contribute significantly to realize the green building specification. The difference opinions between the owners and contractors is relatively small (10.1% or 1 risk factor). The only one risk factor is related to the achievement of the quality of product. The owners thought that the risk was reduced, while the contractors thought the risk was the same with the traditional building projects. It means that the owners expected the contractors that are selected to construct green buildings should be better than others in delivering the products.

In contractual risk category, two or one-third of risk factors are suggested to be removed. They are related to late payment by owner, and contract breach by contractor. This shows a general expectation to a green building project; the more demanding specification of green buildings, the more competent and committed the parties involved in the project. However, the owners thought that two risk factors should have reduced risks, while the contractors thought quite the reverse. Those two risk factors relate to unambiguity of contract clauses and incomplete scope of contract. The owners seems to rely heavily on the selected designer to prepare the contract clauses on green buildings and have confidence in the design product. Because of that, the owners, again, positioned the risk into the contractors' side. Meanwhile, the contractors are worried that many issues are not clear enough in the contract and expected to have a contract that have accommodated the risks of new emerging technologies and practices to support the green building movements.

There are 44.4% of different opinions between the owners and contractors on the labor risk category, or there are four risk factors that gained different perception from them. Those four risk factors are related to safety and health, dispute, labor's satisfaction, and labor productivity. The owners considered the labor issues are the contractors' business, then they thought that the risks should be reduced by selecting the better contractors for implementing green buildings. On the other hand, the contractors thought that the issues remain the same compared to traditional building projects. Both owners and contractors agreed on two risk factors that would elevate in green building projects, they are the availability of skillful labor, and potential overtime works for labor. Two omitted risk factors are related to labor strike and wage escalation.

For material and equipment risk category, the different opinions between the owners and contractors are very obvious (50% or 5 risk factors). Those five risk factors are related to loss of material, late material delivery, inaccurate material delivered, broken equipment, and incorrect equipment selected. Four out of five risk factors were assessed to have reduced risks by the owners while no change by the contractors. Only one risk factor that was assessed to have increased risk by the owners, i.e. late material delivery, but the contractors assessed to have no change in risk. In this case, the owners were aware that materials required by green building specifications might be different to common construction materials and therefore would cause a delay in delivery to the project site. However, when the owners thought that would be reduced or increased risks, they all should be mitigated by the contractors. On the other hand, the contractors always think that the risks are the same. In this material and equipment risk category, there is no omitted risk factors proposed by both respondents.

Conclusion

Green building movements are still in emerging phase and the construction supply chains to support the movements are still considered immature in Indonesia. Construction risks associated with this condition should be taken care of at the beginning of every green buildings' stage in order to reduce the possibility of legal and performance issues related to the green building projects. The more demanding specifications for green buildings could mean a quality assurance for the owners, but on the other hand could raise additional risks if the specifications could not be met by the contractors. The research also found that the additional risk factors proposed by the owners and contractors with their allocations were encouraging for the research since the owners seem to understand the hidden risks that green buildings will generate, and the needs to revise the terms and condition of contract to accommodate the risk associated with green building projects. On the other hand, the contractors as well as the other members of construction supply chains should equip themselves more to answer the challenges given by green building movements since the practitioners that are involved to deliver green buildings are expected to have better performance compared to others.

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Reconversion in the medina of Tunis: a sensitive approach for sustainability in historic environments

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Abstract: *The aim of this paper is to study the urban evolution of the medina of Tunis with a focus on the sustainability dimension of restoration and rehabilitation projects realized in this historic center. It also tries to introduce a new approach in studying urban and social historic centre's evolution: the atmosphere's approach. The interest of this approach is that it allows the consideration of both tangible and intangible aspects of the urban and architectural phenomenon.*

Atmospheres, sustainability, reconversion, heritage, spirit of place

Historic towns' conservation constitutes an important challenge for the international community. Indeed, these historic centres are not only considered for their historic value, but also for their ability to support new lives with contemporary requirements.

The examination of the various texts managing the conservation of these cities informs us on the importance of the challenge to take up. This challenge is all the more important if we consider the sustainable dimension of interventions in such historic areas. In fact, the approach adopted by the international authorities aims, not to 'musefy' these historic centres, but rather to take "those steps necessary for the protection, conservation and restoration of such towns and areas as well as their development and harmonious adaptation to contemporary life" (Washington charter, 1987).

We will try in this paper to study the urban evolution of the Medina of Tunis with a focus on the sustainability dimension of restoration and rehabilitation projects realized in this historic centre. A special focus on the evolution of the atmospheres in the historic centre will be proposed in the second part of this paper.

Urban and social evolution in the medina of Tunis

Like the most part of the Arab Islamic cities, the Medina of Tunis knew its 'golden age' during the ottoman reign, during which most of the city was conceived. Indeed, "the historical city that we know today is a direct heritage of the ottoman period, which lasted more than three centuries" (Saadaoui, 2001). At that time, the Medina was "the single urban fact in the site of Tunis" (Abdelkefi, 1989), and represented the capital of the regency.

From the second half of the 19th century, the city started to change. As well on the social plan as on the urban level, these changes start to be felt. The demolition of the ramparts (1860), the opening of the doors (1870), the new centrality created around the 'quartier franc' and the

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place of ‘Bourse’, and especially the establishment of the new French consulate ‘out of the walls’, all these factors contributed to the creation of a new city at the east of the Medina, which was no more the ‘one and only city’.

“These changes didn't happen in a vacuum. At the same time, the urge to progress by emulating the west was gaining more and more ground; habits, dress, and attitudes were also taking a less traditional tone.”(Hawkes, 2006)

The Medina of Tunis started to lose its power to the benefit of the new ‘colonial’ city and many families began to leave the medina. This process accelerated immensely after the independence. While original inhabitant of the Medina left their homes and moved to ‘modern’ houses deserted by colonists in the ‘new city’, an inverse exodus is registered in the Medina: “rural migrants began to move into the city and take up residence in the empty medina houses, crowding one family into each room. Crowding rose tremendously, and at the same time, the medina fell into a state of urban decay” (Hawkes, 2006).

This critical situation of a ‘dying city’ was not long in causing a general indignation. A movement that founds its apogee with the creation, in 1967, of the association of safeguard of the medina of Tunis (ASM), which will contribute, in 1979, to the registration of the medina on the list of the world heritage.

Since its creation, the ASM was revealed as the protective of the historic town. It imposed itself as an undeniable partner in almost all the projects and interventions in the Medina. Face to a threatened heritage, a fast, but well reflected action was to be undertaken.

Safeguarding strategies and sustainability

ASM’s strategy for conserving and safeguarding the historic area of the Medina was pioneer in terms of sustainability. Indeed, main axes of sustainable development, announced in Johannesburg in 2002 (economic development, social development and environmental protection) appeared already, few years before, among the outlines of intervention’s policy of the ASM.

Actually, the ASM was interested in the beginning in urban and architectural regeneration., with the ‘Hafsia’ project (operation conducted during nearly 12 years on the ancient site of the Jewish district called ‘Hara’, having allowed the construction of 400 houses and shops, twice awarded by the AGA Khan price) and the ‘Oukalas’ project (operation currently in its 4th phase, interesting approximately 1600 households, and having allowed to save 180 000 m² of dwelling floors). Grants were also given in a way to encourage individual housing improvement. Thus, the first phase of intervention in the historic area was accomplished, aiming to “treat insalubrity and slow down degradation” (Akrout Yaïche, 1999). Social development is thus ensured, “we note with satisfaction the starter of a phenomenon of return in the historic town”.

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This social development, as well as the renewal of the population of the Medina, allowed the revitalization of the marketing activities in the historic centre. In fact, with its various souks, the Medina always constituted an important economic pole in the capital region; even while the degradation of the historic centre. This role developed during the last decades: measures were taken for the restoration of the souks and the improvement of the quality of the production and the services. It is indeed part of a global policy started in 1969 by the project of 'conservation and enhancement of the medina of Tunis for economic development', financed by the UNPD (United Nations Development Program).

Hence, we have to specify that various actions undertaken in the historic town are part of 'integrated projects' aiming to the development of the Medina. "Integration means, in the socio-economic field, a social mixing and a mixture of the activities… in the spatial field, it was to result in an urban continuity, obtained, among others, thanks to the respect of the ancient templates and pathways" (Akrout Yaiche, 1994).

This urban continuity is particularly the result of al long combat carried out since the beginning of the previous century. Actually, the medina has escaped distortion of its urban structure on several occasions (Valensi 1920, Cacoub 1958). However, certain interventions were helpful for the historic centre. We note for example the pavement of the streets, the introduction of public lighting and the network of electricity and gas distribution (on the beginning of the 20^{th} century).

Cultural reconversion: a warranty for sustainable conservation

Besides the three pillars of sustainable building, previously quoted (Johannesburg 2002), the 'Paris declaration on heritage as a driver of development' announces the culture as the fourth pillar of sustainable development. This important place given to culture is announced through various international charters and declarations, crowned lately by the declaration of Hangzhou in 2013 regarding culture as a 'key for sustainable development'. It affirms: "culture should be considered to be a fundamental enabler of sustainability, being a source of meaning and energy, a wellspring of creativity and innovation, and a resource to address challenges and find appropriate solutions".

Therefore, the choice was carried in Tunis for the 'cultural revalorization' of the historic centre: "All the Medina with its monuments must radiate like a cultural pole of great value" (Akrout Yaïche, 1999). With this intention, and considering the specificity of the historic site, it was not question of building suitable new spaces, but rather of investing the empty buildings of the Medina. This strategy of reconversion helped to ensure the conservation of the historic centre and to allow its development, giving new lives to its unoccupied buildings.

Thus, the reconversion was the optimal solution to be adopted for unoccupied buildings in the historic centre. Moreover, while settling in the historic palace of 'Dar Lasram', the ASM displayed already this interest: "Instead of luxurious materials of an unspecified dominating taste, instead of a modernistic comfort, we preferred the true luxury: the quality of space;…

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spaces which lend themselves to a multiple appropriation, flexible spaces, non-restraining spaces, differentiated big spaces, non-monotonous" (Abdelkefi, 1989).

A flexible and strong potential of space, a rich history, a new function which will increase the interest carried to these buildings, such is the interest of cultural reconversion in the Medina of Tunis.

Within this framework, several operations were conducted, "several attempts took place to recover left buildings… in order to make them prestigious, radiant places of art and culture, and taking part in the socio-economic promotion of the Medina" (ASM, 1999). These interventions allowed the creation of a cultural circuit, apart from the classical trade one, which tends to integrate the culture in the equation of touristic economy, so that one comes 'to properly consume the city'.

"The old city is not any more that space folded up on itself, shut in, which described Jacques Berque in the thirties. It vibrates with the least social or cultural impulses which agitate the capital region. On the opposite, it transmits messages in the direction of the other districts of the urban area: such conference in the 'Club Tahar Haddad', such concert in the 'Medersa Bir Lahjar', such manifestation in the 'National Theatre' or in 'Kheireddine palace' are the signs of another radiation that of the tradition" (Abdelkefi, 1994).

We will try in the second part of this paper to evaluate the impact of such transformation in the historic centre, through the study of urban atmospheres, in particular after the last operations of cultural reconversion. Such an approach will permit to focus on the in situ sensuous experiences of different users in the historic centre.

Heritage atmospheres: case of the Medina of Tunis

To study the evolution of the atmospheres in the heritage context of the Medina of Tunis, we have first to know more about atmospheres. Indeed, "the values of the building not only relate to the tangible, physical material, but also to the in-between of the materials. This is what we identify as atmosphere, an enveloping phenomenon that surrounds and affects our sensuous system and well-being when we approach, enter, stay or move in a building' (Ventzel, 2012). Thus, atmosphere integrates various items contiguous to space (conformation, forms, materials, colours, lights…) and users (individual character, mood, age, sex…) considered in a particular context (time, social environment, political context…). Consequently, atmosphere is a 'dynamic process'.

In the first part of this paper, we exposed how, from the second half of the 19^{th} century, uses, individuals, and even fragments of spaces have changed in the medina of Tunis. What about atmospheres? What about sensuous feelings and experiences in the historic centre?

First, we have to notice that the urban space in the Medina of Tunis was, for long time, socially controlled: "a fixed social order and regulated communication prevail… This order is created by separating persons, things and actions and allocating them to specialised social

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spaces" (Escher, 2001). Thus, a gender segregation was imposed in the Medina: the presence of women in the public space was 'socially' limited (it is accepted in some souks, or on the roofs of houses), codified (specific clothing according to the age, the social class and the religion), and sometimes rejected (in some specific places like coffee shops). This attitude continued until the first half of the 20th century, and engendered different behaviours and attitudes: the absence of women was such an evidence for local inhabitant, while stranger visitors and travellers were surprised about this segregation. Nowadays, this atmosphere indeed changed. Women presence in the public space is undeniable; they are not only present like momentary 'consumers', but also to manage and conduct shops, trades, cultural centres, and even coffee shops, these spaces having been formerly prohibited for them for so long.

Female presence does not constitute the only change for the users of the historic centre: let us also note the disappearance of animals (especially horses and camels), which animated streets and helped people to move along the districts of the Medina. It would be a madness today to bring a camel or a horse in the historic town (even in the whole city), only cats are welcome.

It is also important to talk about foreigners' presence in the Medina of Tunis. Formerly, the inhabitants of the Medina where from different religions and nationalities: Muslims, Jewish, Christians, Arabs, Bedouins, Maltese, Italians…Therefore, this plurality was quite distinctive: costumes, languages, and even urban space were clearly recognizable for each other. Some important events also influenced the behaviours of the ones: Arab Muslims, generally pleasant, become hostile towards Christians after the occupation of Algiers.

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Figure 1: The Suq Blat (herb and spice market) in the medina ofTunis (Soupault 1988).

Figure 2: A street in the quartier 'Rue du Pacha' during the 'Dream city' festival (source: www.tuniscope.com)

Nowadays, the only noteworthy foreign presence in the Medina is that of the groups of tourists. They are generally welcome and well received in the historic town, especially in the souks.

Let us talk more about these souks. Several souks kept their original vocation, in particular the souks near the Great Mosque. They also kept a part of their atmosphere: environment is always marked by these “light clouds of subtle perfumes” in the ‘Souk El Attarine’, “this voluptuous debauchery of sharp and deadened colours” in Souk El Kmach, and this ‘hammering of the blows’ in Souk Ennhas (Baraudon 1893). It is however to note that certain uses disappeared, in particular the sale of the slaves in the Souk El Birka. Other uses quite simply evolved, as the water salesman who submitted his copper instrument by a wheelbarrow filled with bottles of water covered with ice, or the public storyteller whom private circles of listeners left room for ‘cultural cafés’ accommodating various specialists (historians, sociologists…) recalling the glorious history of our ancestors.

Whole districts even changed vocation. We can mention for example the district of the ‘rue du Pacha’, a residential district for the ‘bourgeois’ families of the 18th/19th century, that, especially with the ‘cultural’ policy adopted by the ASM for the valorisation of the Medina,

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currently has “a significant role in the artistic life of the capital, ... The ASM call this district the ‘cultural district’ of Tunis” (McGuinness, 2002).

Even sounds and cries evolved in the Medina: the carrier or the travelling merchant who once shouted “Belek” (take care), opts today for “saqik” (take care of your feet).

All these atmospheres are, indeed, a part of what ICOMOS[1] called in 2008 the “spirit of a place”[2], in this case, the spirit of the medina of Tunis. The identification of some “memories … rituals … values, textures, colours…”[3] is in fact a first step to be taken in recognizing the spirit of places. In the case of the Medina of Tunis, reusing of urban and architectural spaces for new functions helped them to escape destruction and to have a new life. Thus, it ensured that the “continuously reconstructed process”[4] continues until today.

Conclusion

Between the Medina of Tunis at the end of the 18th century, and that at the dawn of the 21st century, much of things changed and/or evolved: people, practices, spaces, atmospheres, … but we cannot deny the subsistence of certain elements that would constitute the constant in all these changes: Tunis is always “White”[5], its souks are always animated either by local or foreigners, its Souk of the perfumers (Souk El Attarine) always make its visitors ‘drunk’ by its scents, and that of the fabric always dazzles by its colours; its ‘sabbats’ (covered alleyways) are always fresh, and the visitors still lose themselves in its ‘labyrinthic’[6] roads. Even the call of the travelling merchant, while evolving, keeps always its first significance.

The study of the evolution of the atmospheres in the Medina of Tunis, briefly advanced above, is an attempt to introduce a new approach for the multidisciplinary study of the urban centres, in particular the historic ones. It allows particularly the simultaneous consideration of a material qualification of the site, and of a sensuous characterisation of studied zones. An importance is also allocated for the consideration of the atmosphere as a “stimulation motor” able to define and direct choices and behaviours in urban and architectural spaces.

This paper also aimed to illustrate the outlines of the Tunisian approach in sustainable conservation of historic sites. The Medina of Tunis certainly evolved during these last centuries, but it always preserved its important role in the economic and social life of Tunis. It is certainly no more “the only urban fact” of the city, it does no more concentrate, ‘among its walls’ the centre of the political power, but it still denotes an undeniable interest and an unquestionable value for the country’s life and development. The cultural policy adopted in the Medina during the last decades finally allowed the reconciliation of the capital region with

[1] International Council on Monuments and Sites
[2] Quebec Declaration on the preservation of the spirit of place, adopted at Québec, Canada, October 4th 2008.
[3] idem
[4] idem
[5] The adjective ‘White’ (la Blanche) is currently used to describe the Medina of Tunis in many travel stories in the end of the 19th century. One novel have it for title: Harry, Myriam, *Tunis La Blanche,* (1910)
[6] As for the adjective ‘White’, many travellers use the adjective ‘labyrinthic’ to describe the roads and alleyways of the Medina.

its historic centre, thus allowing its reintegration in the social, economic and cultural life of the city.

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Session 123:

Are energy simulations really reliable?

Chairperson:

Sánchez-Guevara, Carmen

Universidad Politécnica de Madrid, Spain

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The missing energy
Improving the study of heat fluxes in buildings

Speaker:
Ll. Viader, Roger

[1] LiTA-UPC. Sant Cugat del Vallès Catalunya, Spain

Abstract: *Efficient thermal insulation has so far focused on improving building's envelope, understanding a building as a unique thermal space. Although it could be the case for some kinds of constructions, because of the more independence of each person and the concentration of people in multistory buildings, there are more partitions between different heated spaces and it makes us wonder about the relevance of thermal energy loses through these interior partitions. Aiming to answer this question, we divided our research into two main steps: first basic calculations of different building typologies, and developing an accurate virtual model to represent this phenomenon. In our first approach we looked for some numbers of what this yet-non-studied energy flow could represent to the whole energy flux in two different building typologies by using a monitoring system named SIRENA from Universitat Politècnica de Catalunya (http://www.upc.edu/sirena). How relevant are interior losses compared with losses through the building's envelope? Are those losses hight enough to be studied and improved? The answer is rotundly "yes"! We concluded that this loses represents about a 20% of, what we named, a "Uni-Thermal-Zone Building (UZB) total loses and this value gets specially remarkable when rises to more than 70% in case of multistory and residential buildings, named as "Multi-Thermal-Zone Buildings" (MZB). Thus, according to our results, the significant percentage of heat lost through interior partitions indicate that they play a key role in a building's thermal fluxes. As a consequence, we developed a DesignBuilder thermal model with different utilization patterns to analyze how this energy flow affects the interior comfort in a MZB, which are the south of europe most extended type of building, during one day and how the energy is lost. The results suggests thinking about "thermal sectorization".*

Keywords: Energy efficiency; Indoor heat transfer; Indoor heat flux; Internal partitions thermal insulation; occupancy patterns; Modeling of heat transfer in buildings.

Summarized paper

1. Introduction

The following ressearch represents an improvement and a step forward into understanding what may happend in our thermal balances in were there are always some losses wich cannot be identified, regarding the one presented in SB13_München Congres by Roger Llorens Viader, in where it was pointed out that it is true that thermal efficiency can still be improved and focussed on inthernal heat fluxes and how is it transmited between different internal spaces through interior partitions, representing an inhabitant's confort improvement.

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For some years now our country (spain) has been working towards a greater efficiency in the use of energy through passive measures such as the improvement of thermal insulation of building's enclosure walls that enable it to lower its cost. Although this field has experimented a huge rising, it is fairly clear that this progress was headed in one direction only: improving the external envelope.

It is true that the greatest amount of heat loss occurs through these enclosure walls. Nevertheless, and as it was proved in the full paper, which can be found in Catalan Polithecnical University digital archive through the following link: http://minilink.es/gp9, once exterior walls are improved, we realize we still have heat losses in our buildings probably through openings, ventilation systems, towards the interior of the building through internal partitions and so on. This is what we call "The missing energy case".
This research will attempt to identify and quantify one of these possible thermal vanishing points using different thermal measurements and computational modelling. The phenomenon to be recognized in this project is the one on thermal losses through interior partitions that divide properties or spaces with different degrees of climate control.
The building tradition within the Spanish state displays a systematic lack of thermal insulation in these partitions, since the *Codigo Técnico de la Edificación* (CTE) has not included them explicitly until 2006. Currently, due to a much more dynamic and heterogeneous society where individuals are becoming more and more independent from their environment, we believe it to be necessary to review this lack of thermal insulation of interior partitions and contemplate the effectiveness of incorporating, or not, thermal insulation in its composition.

1.1. Goals

The main aim of this research is to continue the research presented on SB_13 München by Roger Llorens Viader representing LiTA Lab in where were presented the firsts studies of this "missing energy" that we can't idetify in our thermal balances because it is not lost through the external skin of buildings but interior partitions.

In this case we look forward to go dipper in muty-storey building's heat transfer focussing in what happens interiorly in order to open new devates to finally improve building's thermal efficiency theories and procedures.

1.2. Initial hypothesis

As thisis the second stadge following "Relevance of interior thermal fluxes through buildings' interio partitions" research by Roger Llorens from LiTA-UPC, whe already have some initial hypothesis verified such as:

:: Basic fluid mechanics theory. The temperature difference between two spaces will cause the energy flux through the partitions separating them.

:: The more insulated the building façade is the more the percentage of internal thermal loses will grow since, if untreated, the phenomenon will keep within constant values while we continue decreasing the energy transmission to the outside. This leads us to think that, in order to improve the energy efficiency of the buildings, it is necessary to consider both interior and exterior enclosure walls as "thermal frontiers" that must be treated simultaneously.

:: In buildings such as public facilities, managed by only one main air conditioning system, the interior thermal transmission will be less relevant due to the large volumes of air to move, the homogeneity of uses and the interior temperatures.

:: In residential buildings such as collective apartments or hotel complexes, the great fragmentation of spaces into little unities means a larger contact area between internal spaces with different levels of heating. Hence we suppose that there will be a higher percentage of internal losses. A priori, we assume that this sector is the most appropriate to apply our theories.

With these statements proved and accepted, more hypothesis can be developed regarding these residential buildings in where ara a lot of different people living lives together with different abits and a large number of thermal interactions between dwellings.

First of all, I would like to clarify that we have used Spain's most common heating sistem in where each inhabitant in the bloc can set the temperature of its dwelling independently so, we have a high range of different temperatures and utilization timings in the same building. Actually, this will be a key point in the ressearch as will be seen below.

:: In a residential bloc, there will be some different utilization patterns deppending on each individual heating habits wich will depend in some parameters wich will make the indoor heat in the building easily flow from one space to the other what may interior partitions become external walls (because of a great temperature difference) in some cases.

:: More exterior dwellyngs may not be the ones that looses the greater amount of energy in the building. Because of the previously mentioned utilization patterns will appear some units/dwellings that can steal heat from adjoining units wile others just give energy so, there may be a thermal inefficiency for the user who will be heating others spaces.

1.3. Previous ressearch

In order to summarize the previous steps developed in the first stadge of this investigation, it was divided into two main first stages: Study of one Uni-thermal-Zone Building (UZB) and Study of one Multi-thermal-Zone Building (MZB). We were able thus to do a progressive approximation to the phenomenon as increasing the complexity of each step.

:: Typology 01. Uni-thermal-Zone Buildings [UZB]
First, we focussed on doing the preliminary verification of the phenomenon in the “Escola Tècnica Superior d’Arquitectura del Vallès’ building”, which is linked to the Catalan Polithecnical University [UPC - ETSAV]. We carried out a measurement protocol in where it whas checked that heat flows through interior partitions from one interior space to another to finally develop a basic calculation model in where we were able to compare internal loses with exterior loses.

:: Typology 02. Multi-thermal-Zone Buildings [MZB]
After this first aproach, we went through multystorey buildings. In the previous research it was developed a basic calculation model in order to be compared with the one developed in UZB an consequently it was basic in a synchronic situation and a theoric model. However, results where so significant that we have developed the present research as a final step to prove the phenomenon's relevance with advanced simulation.

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1.4. Previous ressearch :: Results

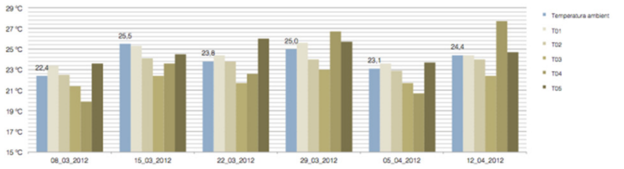

Fig.1: ETSAV's Auditorium thermal monitoring

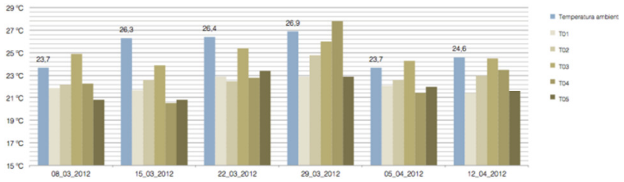

Fig. 2: ETSAV's Library thermal monitoring

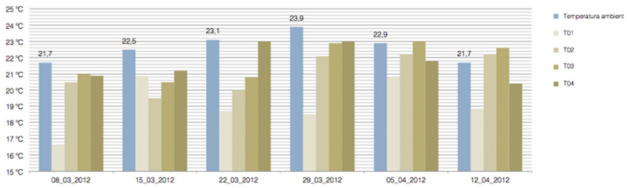

Fig. 3: ETSAV's Computer room thermal monitoring

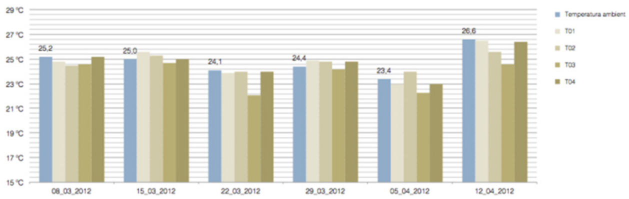

Fig. 4: ETSAV's 24h-work-room thermal monitoring

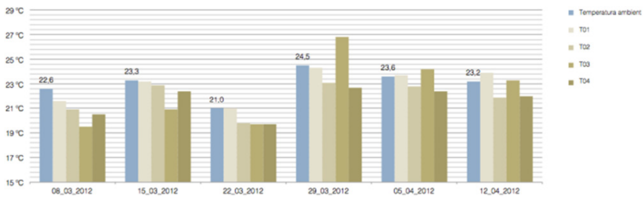

Fig. 5: ETSAV's shop thermal monitoring

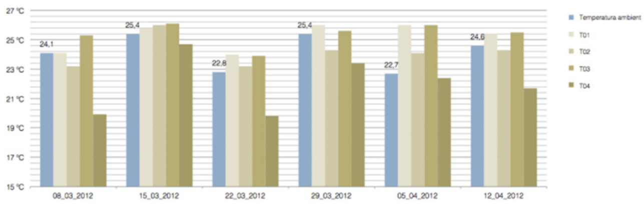

Fig. 6: ETSAV's bathroom thermal monitoring

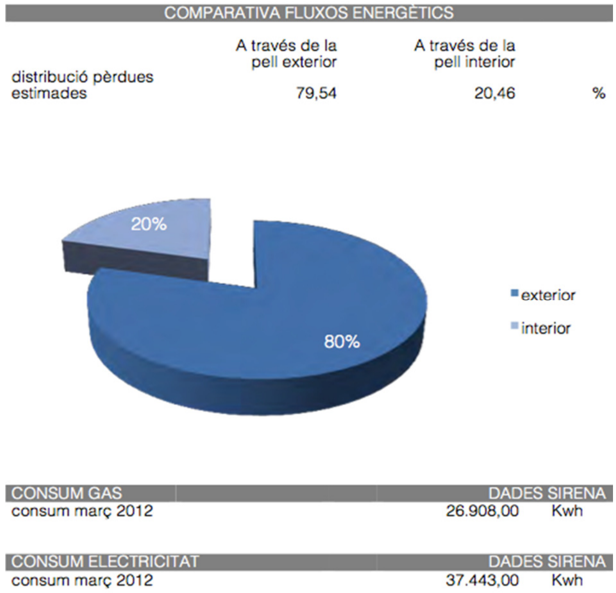

Fig. 7: Thermal loss through interior/exterior partitions

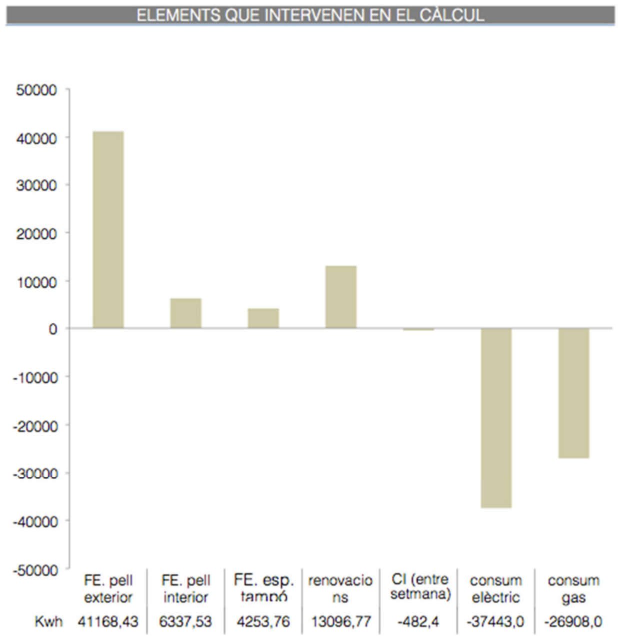

Fig. 8: parameters involved in UZB calculation

With the first campaigns carried out in UZB, we can begin to draw reliable conclusions that will benchmark our first hypothesis thanks to the data extracted from the previous exercises. If we keep the development process in perspective we can corroborate most of our initial hypothesis:

:: Once we have done our small scale measurements, we have expanded this scale of work throughout the evaluation of the building, while not limiting ourselves to observation only, we have done a more detailed analytical approximation of the factors involved in the heat balance fluxes. At the same time, we have confirmed that these transmissions constitute 20% of thermal losses in a building such as the ETSAV.

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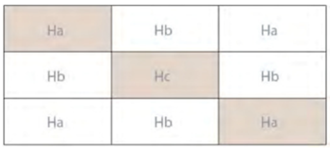
:: We have confirmed that the ETSAV building as chosen prototype to carry out the evaluation, contributed several circumstantial variables that hinder the contrast of the expected results- 80% of energy loss through the façade is due to the large number of thermal bridges, the poor efficiency of its exterior walls, especially in the use of simple glass, and a large contact surface. In this sense, the number of unheated interior spaces is also reduced and could it thus be considered that the results obtained from the 20% correspond to a cautious scenario. Therefore, we can state that in a building with these characteristics, the usual minimum value of the thermal loss through interior walls rounds up to about 20% of the total flux of heat contributed.

:: Finally, we wonder that this phenomenon takes up a main role in well-insulated buildings, or those in which thermal efficiency in façades has been taken into account during ithe designing stage. We consequently expect the problem of thermal loss through interior partitions to be more relevant in thermal efficiency oriented buildings.

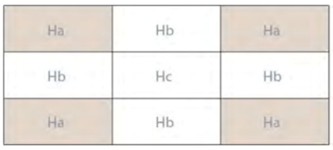
1.5. Previous ressearch :: Results

1.5.1. simple combination results



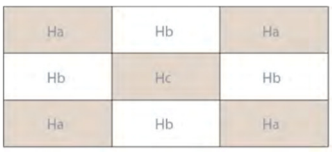
Ha :: coberta	on	x1 / 2	1.211,04	kWh
Ha :: solera	on	x1 / 2	1192,24	kWh
Hb :: coberta	off	x0 / 1	0	kWh
Hb :: solera	off	x0 / 1	0	kWh
Hb :: façana	off	x0 / 2	0	kWh
Hc :: central	on	x1 / 1	1582,69	kWh
FLUX TOTAL			3985,97	kWh
FLUX PONDERAT / UT ACTIVADA			1328,66	kWh

Fig. 9: simple MZB combination 01



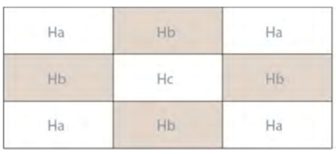
Ha :: coberta	on	x2 / 2	2.422,09	kWh
Ha :: solera	on	x2 / 2	2384,47	kWh
Hb :: coberta	off	x0 / 1	0	kWh
Hb :: solera	off	x0 / 1	0	kWh
Hb :: façana	off	x0 / 2	0	kWh
Hc :: central	off	x0 / 1	0	kWh
FLUX TOTAL			4806,56	kWh
FLUX PONDERAT / UT ACTIVADA			1201,64	kWh

Fig. 10: simple MZB combination 02



Ha :: coberta	on	x2 / 2	2.422,09	kWh
Ha :: solera	on	x2 / 2	2384,47	kWh
Hb :: coberta	off	x0 / 1	0	kWh
Hb :: solera	off	x0 / 1	0	kWh
Hb :: façana	off	x0 / 2	0	kWh
Hc :: central	on	x1 / 1	1582,69	kWh
FLUX TOTAL			6389,25	kWh
FLUX PONDERAT / UT ACTIVADA			1277,85	kWh

Fig. 11: simple MZB combination 03



Ha :: coberta	off	x0 / 2	0	kWh
Ha :: solera	off	x0 / 2	0	kWh
Hb :: coberta	on	x1 / 1	1252,59	kWh
Hb :: solera	on	x1 / 1	1233,78	kWh
Hb :: façana	on	x1 / 2	2164,08	kWh
Hc :: central	off	x0 / 1	0	kWh
FLUX TOTAL			4650,45	kWh
FLUX PONDERAT / UT ACTIVADA			1162,61	kWh

Fig. 12: simple MZB combination 04

QUADRE RESUM DE PERDUES TERMIQUES SEGONS POSICIO D'HABITATGE			
	Pèrdues a través dels tancaments exterior	Pèrdues a través dels tancaments interior	TOTAL
Ha :: coberta	2,33 kWh 42,3%	3,18 kWh 57,7%	5,51 kWh 100%
Ha :: solera	2,24 kWh 41,4%	3,18 kWh 58,6%	5,42 kWh 100%
Hb :: coberta	1,43 kWh 25,1%	4,27 kWh 74,9%	5,70 kWh 100%
Hb :: solera	1,34 kWh 23,9%	4,27 kWh 76,1%	5,61 kWh 100%
Hb :: façana	1,74 kWh 35,4%	3,18 kWh 64,6%	4,92 kWh 100%
Hc :: central	0,84 kWh 11,7%	6,35 kWh 88,3%	7,19 kWh 100%

Fig. 13: Thermal loss through linterior/exterior partitions in MZB simple

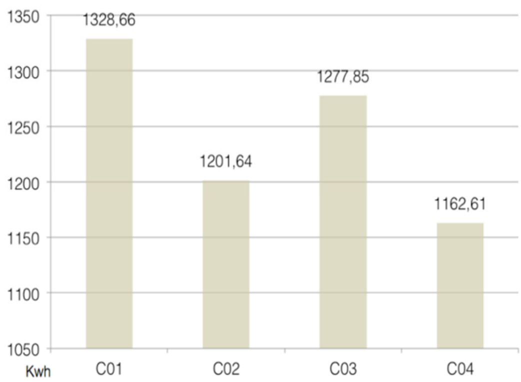


Fig. 14: Total energy loss in C01 to C04 combinations

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1.5.2. complex combination results

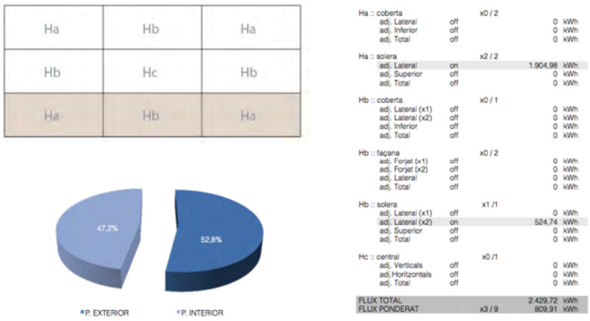

Fig. 15: complex MZB combination 05

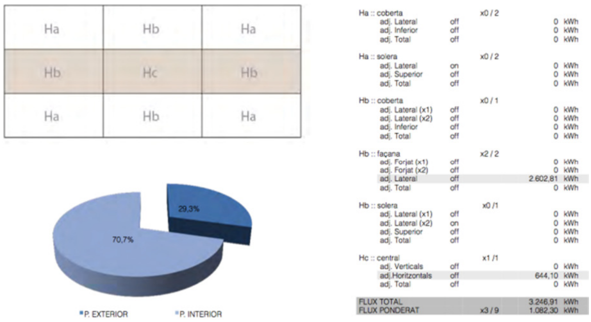

Fig. 16: complex MZB combination 06

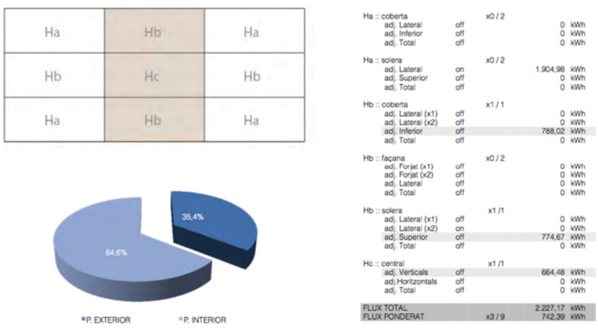

Fig. 17: complex MZB combination 07

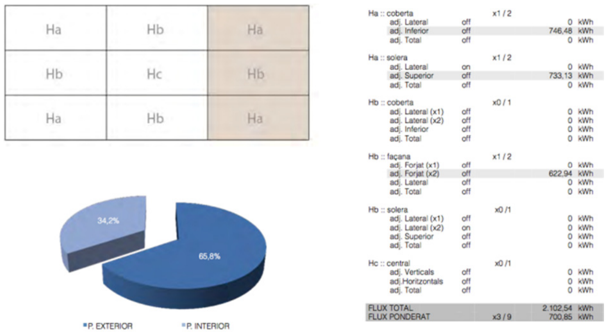

Fig. 18: complex MZB combination 08

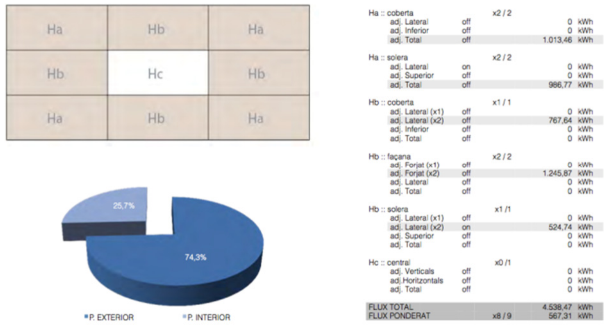

Fig. 19: complex MZB combination 09

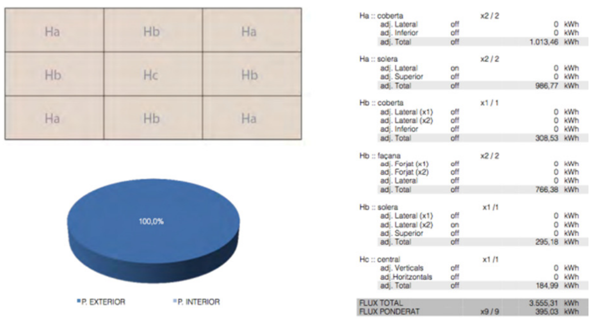

Fig. 20: complex MZB combination 10

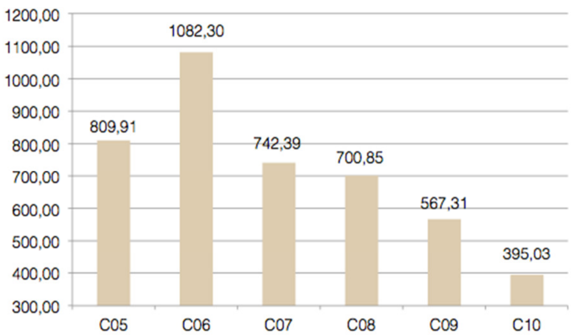

Fig. 21: Total energy loss in C05 to C10 combinations

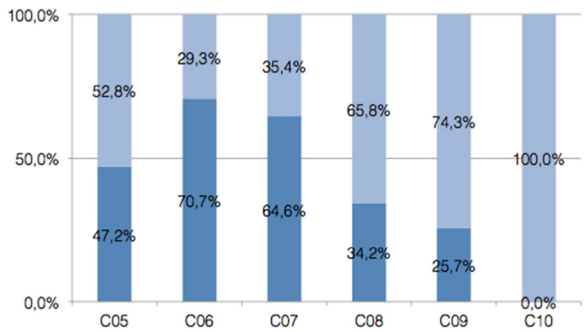

Fig. 22: Thermal loss through interior/exterior partitions

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According to the MZB, which could represent all the residential buildings managed by individual thermal generators, we can confirm that this building type is more affected by this phenomenon. The typical features of this type of constructions, with very small units, as could be seen in the different houses in a block of flats or rooms in a hotel complex, naturally lead to this result. There are lots of clearly defined spaces with different utilization patterns and heating protocols. According to our models, we found out that depending on the situation of the studied unit within the building as a whole and above all of the occupation and at the same time air conditioning units around it, the values relating to the thermal loss through the interior partitions is ranged between 25.7 % and more than 70 %. This proves that these enclosure walls are truly relevant to the flux of thermal energy and we therefore believe that they are the next huge topic to consider in the improving of the thermal efficiency of residential buildings, as they represent the most extensive building type in all developed world.

Finally, we can confirm that the strategy that would give us the best efficiency regarding the thermal efficiency of the entire building in a synchronous model, for instance, in a single instant of time, is to activate all units at the same time, avoiding the largest number of thermal breaks and therefore reducing the surface thermal transmission in the façade, which is supposed to be correctly insulated. This strategy reduces thermal losses up to 63.5% but is not very widespread in our country so, and to make it more realiable, we will develop a *DesignBuilding* advanced modalization to try to simulate some user/heating patterns algong one day.

2. Methodology

In order to organize this new research step, it was precised to use realistic data and anadvanced software. First of all, and in colaboration with Maruixa Toucedo and Javier Neila from Technology department at Escuela Técnica de Arquitectura de Madrid (ETSAV) part of Universidad Politécnica de Madrid (UPM), a virtualized building was designed by using *DesignBuilder* simulation software.

In order to make the following results comparable to the ones obtained from the first research, we have simulated the new building in the same climate as the first exaple: Barcelona, Catalunya in a North-East orientation. In order to simulate it is an operative building during the whole year, although we have made the simulation from February 20th to April 1st hour by hour, mesurements for future calculations has been taken from May 15th expecting it to be fully heated and stabilized.

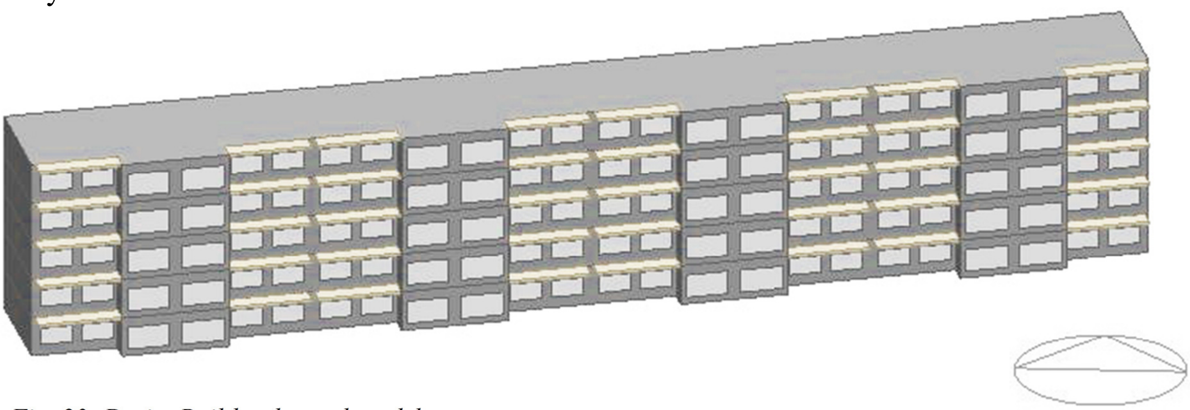

Fig. 23: DesignBuilder thermal model

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Turning to small units, it has been determined that all of them are heated with most common climatization system in Spain: individualized heaters and HVAC systems. Actually, this system is the key point of the whole research because it is what gives building's large number of different heated spaces, what then creates the indoor heat flux and makes some users to loose energy while others gain it.

Acordingly, some user patterns has been determined from 2012 INE data (Instituto Nacional de Estadistica, from Spain) which were used to determine which inhabitants agrupations are the most common in this country and how much are they in percentage. This will allow us to simulate different kinds of utilizations patterns with different timetables and so, different heating levels.

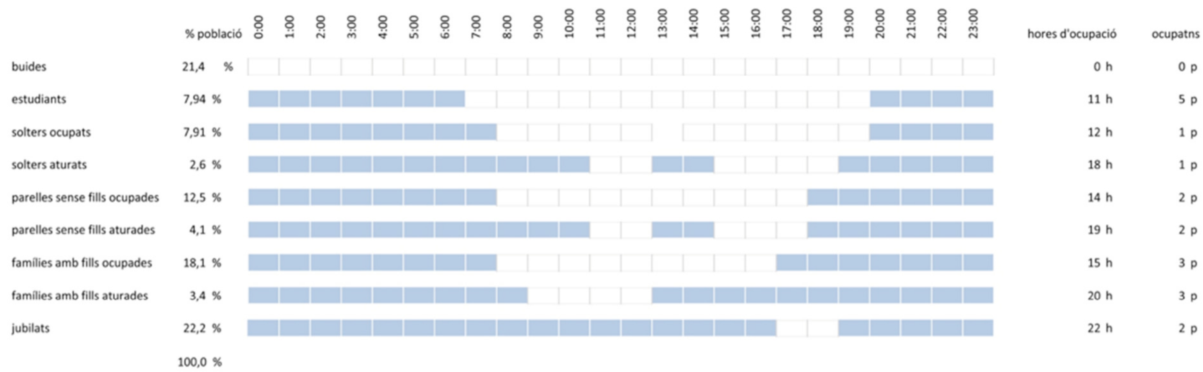

Fig. 24: Utilization Patterns features

Finally, the procedure will be to put them into the building strategycaly but mainly randomly in order to simulate a real building in where no one is able to control other's heating protocols and at the same time could represent a significant portion of Spanish society.

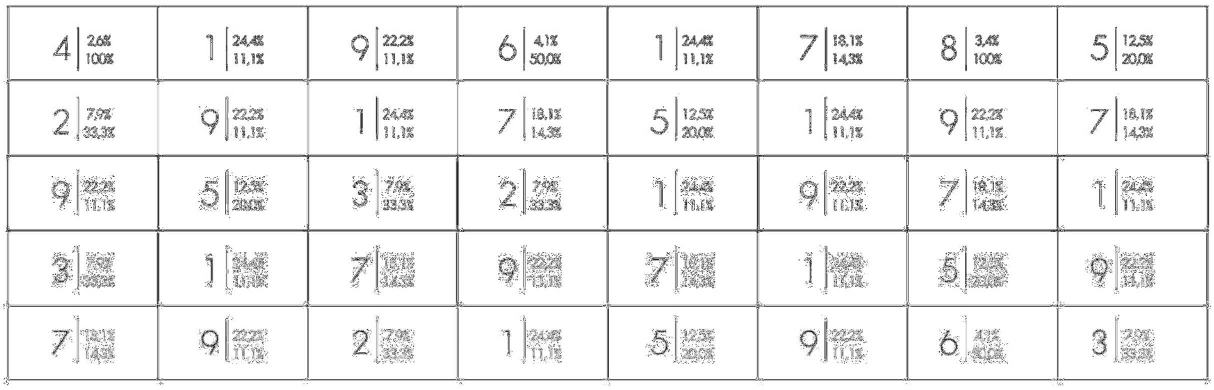

Fig. 25: UtilisationPatterns situation and quantities

With this first data summarized in this dwellings block, we managed to simulate its heat indoor flux in order to finally see if it could be a future improvement in Thermal Efficiency therories or if in the other hand it doesn't look important enough. As results will show, we are facing a very important phenomenon wich will bring us the key for users thermal efficiency, confort and money saving improvement.

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4. Simulation: Nation Representative Block.

Tha last step in this research, is to put together all the basic data and hypothesis results to build up a complex simulation with *DesignBuilder* in order to introduce the time parameter variations in a building that could represent the average population of a whole country.

See in *Fig. 30*, software results that concerns to our research, which represent the energy lost from each space through every surfice in order to start developing some easy-understanding graphics showing thermal energy flux and where the energy is lost through.

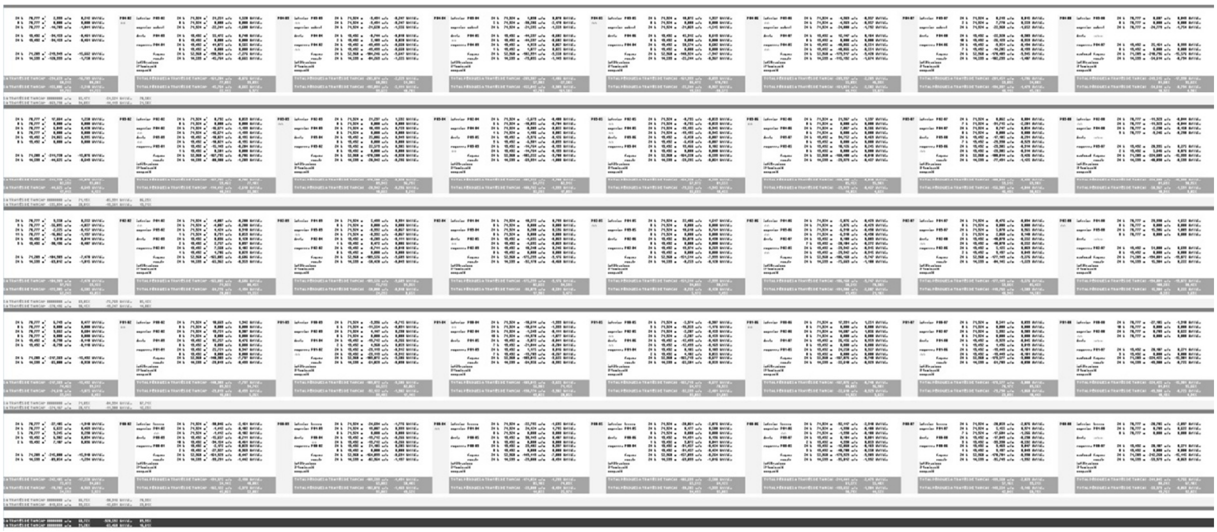

Fig. 26: DesignBuilding graphically-arranged numeric results

More closely, each dwelling modelized looked like the following table where it is shown the quantity of heat lost through all partitions during both, the most expected transmision periods and the whole day.

P00-02	inferior	terreny	24 h	71,924 m²	-30,046 w/m²	-2,161 kW/dia
	superior	P01-02	24 h	71,924 m²	-1,412 w/m²	-0,102 kW/dia
		buida	24 h	71,924 m²	-1,412 w/m²	-0,102 kW/dia
	dreta	P00-03	24 h	13,492 m²	-15,657 w/m²	-0,211 kW/dia
			10 h	13,492 m²	-34,154 w/m²	-0,461 kW/dia
	esquerra	P00-01	24 h	13,492 m²	-2,172 w/m²	-0,029 kW/dia
			2 h	13,492 m²	-27,327 w/m²	-0,369 kW/dia
		façana	24 h	52,360 m²	-161,329 w/m²	-8,447 kW/dia
		escales	24 h	14,533 m²	-99,231 w/m²	-1,442 kW/dia
	infiltracions					
	il·luminació					
	ocupació					
	TOTAL PÈRDUES A TRAVÉS DE TANCAMENTS EXTERIORS				-191,375 w/m²	-2,190 kW/dia
					54,14%	48,00%
	TOTAL PÈRDUES A TRAVÉS DE TANCAMENTS INTERIORS				-162,122 w/m²	-2,373 kW/dia
					45,86%	52,00%

Fig. 27: DesignBuilder graphically-arranged numeric results

As we know it is a very complicated simulation, we have just taken into acount engergy from heating systems, climate and situation. As it can be seen in Fig. 31, we expect in the future to be able to involve ventilation, lighting and people heat too.

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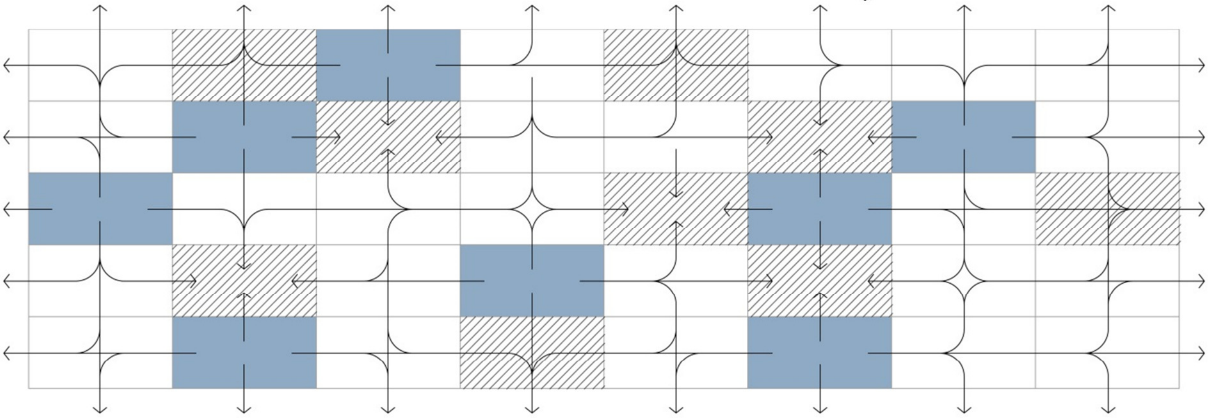

Fig. 28: DesignBuilding flow simulation chart. *Most heat looser units* *Empty units*

11,72%	6,97%	48,70%	72,42%	30,57%	52,07%	45,20%	4,38%
4,12%	22,90%	3,21%	17,09%	18,45%	4,62%	30,02%	9,65%
46,85%	11,55%	8,65%	5,47%	1,49%	21,10%	14,58%	1,63%
6,49%	5,26%	17,14%	28,85%	21,68%	3,62%	10,44%	4,34%
5,32%	52,0%	49,52%	25,97%	35,88%	41,52%	60,79%	32,32%

Fig. 29: Losses though interio partitions *>10%* *>20%* *>40%*

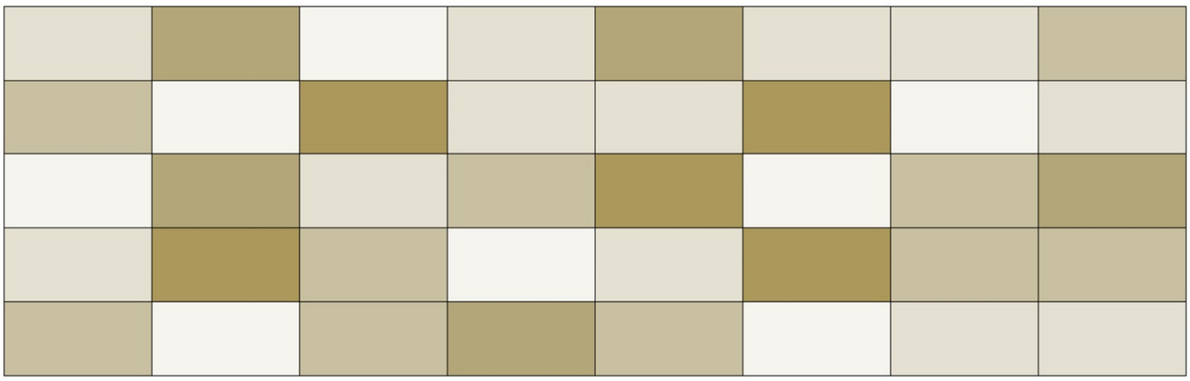

Fig. 30: Most energy-givers units *Most energy-thieves units*

With DesignBuilder results, we are able to develop the firsts charts and get conclusions:

Fig. 28: Energy flow balance after a whole day testing once the building has been fully heated. It can be appreciated how energy moves inside the building through interior partitions.

Fig. 29: It has been calculated how much energy is lost through exterior walls and interior partitions. As it can be seen, 62,5% of total units has at least a 10% of its energy lost through interior partitions. Then a 42,5% loses more than 20% through them, and finally there is a 22,5% of units that loses even more than 40% if its total heat through interior partitons.

Fig. 30: Finally, it has been deduced that within the same block, there are some units giving heat to other units and some others who steal it.

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3. Conclusions

To summarize both researchs into some general conclusions, once having seen all the results together, we can say that we have come up with most of the answers of the hypothesis initially raised. Following a complexity-rising procedure, it has been proved through different methods and in different types of buildings that indoor heat losses through interior partitions is something that exists and can reach very important values that should be minimized in order to acheave a full energy efficiency in some typs of buildings.

According to the UZB managed by a single thermal generator, we find out that the value of these losses can reach up to 20.46%, which is a significant amount, bearing in mind that we are talking about buildings with a lot of volume and therefore a high thermal homogeneity. In addition, it must be remembered that the building chosen for this study, the ETSAV building, has a very little thermally efficient façade since, for example, all the overtures, which represent a 35, 4% of the façade's surface, are resolved with simple glass and aluminium frames without breaking of thermal bridge. Therefore, if we would decide to improve the thermal efficiency of the façade, we would see the losses value through the interior edge would droping enormously and in consequence the 20.46% value that we obtained with our first simulation would increase extremely in comparison with the results that we could achieve with a thermal efficiency façade improvement. Consequently, we believe that for this type of buildings, it is necessary to do a strategic thermal sectionalisation in order to minimize the internal losses.

According to the MZB, which could represent all the residential buildings managed by individual thermal generators, we can confirm that this building type is more affected by this phenomenon. The typical features of this type of constructions, with very small units, as could be seen in the different houses in a block of flats or rooms in a hotel complex, naturally lead to this result. There are lots of clearly defined spaces with different utilization patterns and heating protocols. According to our models, we found out that depending on the situation of the studied unit within the building as a whole and above all of the occupation and at the same time air conditioning units around it, the values relating to the thermal loss through the interior partitions is ranged between 25.7% and more than 70%. This proves that these enclosure walls are truly relevant to the flux of thermal energy and we therefore believe that they are the next huge topic to consider in the improving of the thermal efficiency of residential buildings, as they represent the most extensive building type in all developed world.

In this line and after completing our research with the most sophisticated simulation software, we realize that we have two main possibilities to improve interior thermal efficiency as suggested by proffessor Ray Galvin from Aachen University. The first one, is through education and management. As we have seen, utilization patterns are a key point in interior thermal building's efficiency. Consequently, it can be teached some utilization abits and combine these abits with a correct recources management in order to, for instance, keep some strategically units always heated to reduce big interior temperature differences or, in a more advanced scen, create a heated ring all around the building to reduce the need of heating of interior units giving this way a homogenious temperature in all units with a low variation pattern and consequently a low energy consumption.

The second and, may be, more direct way to avoid these looses could be by start thinking about buildings of an agglomeration of little individual and auto-regulated spaces in where each person is able to determine his dwelling temperature. To acheave this freedom for the user we should invest more resources in a correct isolation of interior partitions because with this model, what we finally get are little isolated units with no interior partitions.

Both theoryes has to bee deeply analyzed but the most probable conclusion is that each solution will be chosed depending on the country in which it is applied regarding climate, heating abits, most extended climatization system and some other parameters that would have to be taken into account. In any case, this first approach to the phenomenon represents an open gate to further investigations leading to a complet thermal efficiency in buildings.

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- Arcadi de Bobes.
- Eduard Bravo.
- Antonio Guardia.

RWTH-Aachen University.
- Raymond Galvin

6. Further research

- In-deep analisy of DesignBuilder simulation Results.
- Technical solutions for Energy Retrofiting Interventions. Thermal sectorization.

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Improving office building energy efficiency by smart engineering and computer simulation: a case study from Australia

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Abstract: *ISPT, an Australian property fund manager, has a substantial investment in sustainable buildings. ISPT's approach to reducing energy consumption in its office buildings uses cost-effective solutions driven by a smart-engineering–computer-simulation (SE–CS) approach. These improvements are rated using the National Australian Built Environment Rating System (NABERS), a performance-based tool that rates energy efficiency from 1.0 to 6.0 stars. The approach includes a detailed inspection of a building's mechanical–electrical systems, computer simulations of energy use, cost–benefit analysis, replacement/upgrade of equipment and systems, and optimization. A case study of a Sydney office building shows that its NABERS energy rating has improved from 3.6 stars (2010–2011) to 5.4 stars (2012–2013), reflecting a 48% reduction in energy use, and saving $530,000/yr. Submetered monthly electricity consumptions for the various functions/systems of the building for 2008–2014 show reductions that correspond to the equipment and systems upgrades. The use of SE–CS methods in the sustainable property industry should generate environmental and financial benefits for a variety of stakeholders.*

Keywords: office building, NABERS, sustainable property industry, Australia, energy use, smart engineering, computer simulation

1 Introduction and background

Organizations in Australia now need to proactively manage the environmental aspects of their activities, including in the operation of buildings, whether as owner or occupier. The private property/building sector is rapidly adopting green strategies, under the drivers of government policies, returns from sustainable (cf. conventional) buildings, and stakeholder expectations. The drivers include the penetration of the NABERS (National Australian Building Environmental Rating System) scheme into the commercial property market as an indicator of sustainability in the property industry for both new and refurbished buildings [1]. This paper examines the ways in which the Industry Superannuation Property Trust (ISPT), a large Australian property fund manager, is improving the environmental performance of its leased office building stock with respect to energy efficiency. ISPT's approach involves: (1) identifying lower-performing buildings through energy consumption data; (2) identifying improvements by inspecting existing mechanical–electrical systems and performing computer simulations; and (3) realizing the improvements by upgrading and optimising the building's systems. A case study of a Sydney office building exemplifies the smart-engineering–computer-simulation (SE–CS) approach. The study is made in the context of the commercial realities of the sustainable property industry, where buildings represent the assets/income of owners/investors, and where the NABERS environmental efficiency rating scheme allows building owners, investors, tenants, and other stakeholders to evaluate and compare buildings.

1.1 The National Australian Building Environmental Rating System (NABERS)

NABERS is a performance-based rating system that provides a rating based on the actual (measured) environmental performance of a building during its occupation/use. The system, which started in 1999, incorporates four components: energy, water, waste, and indoor

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environmental quality. The NABERS energy tool rates a building from 1.0 to 6.0 stars (in half-star intervals) according to its measured performance using 12 months of energy use (obtained from the building's electricity/gas invoices and meters), with the rating being valid for one year. Lower utility consumptions are awarded higher NABERS ratings, although greater degrees of energy efficiency are required to attain equivalent increments in NABERS rating as star ratings increase. There are two main NABERS energy rating systems available for office buildings. One is the 'base building rating', covering the energy consumption resulting from the central building services supplied/managed by the landlords/operators of the buildings, such as heating, air conditioning, and lifts/elevators, and also energy consumption from common areas (i.e., areas of the building shared by different tenants, such as foyers, stairs, and designated meeting rooms). The other is the 'tenancy rating', covering energy use in the areas and activities that are under the control of office tenants, such as office lighting and computers. The separation of base building and tenancy consumption for NABERS ratings is the usual case and means that tenants' behaviour does not affect the level of efficiency established by the building owner for the base building services.

1.2 The sustainable property industry in Australia

Sustainable buildings include both newly constructed buildings and existing buildings refurbished to a high level of environmental performance. These buildings are superior to conventional buildings with regard to better environmental performance (e.g., lower utility consumption), higher rents, higher valuations, improved occupancy rates, lower tenant turnover, and improved occupant well-being [3][4][5][6][7][8]. This correlation between buildings' environmental features/performance and investment returns is attractive to investors, who expect higher returns for higher levels of environmental certification. A 2011 study of the investment performance of buildings with respect to their environmental ratings for 570 buildings in Australia showed a clear advantage of green-ness [7]. For NABERS energy, the annualized 2-yr return for the office market was 5.4% for 5 star, 4.4% for 4 star, and 1.6% for unrated. The IPD Australia Green Property Index was launched in 2011, and data for the Australian CBD office market show that assets rated with NABERS energy at 4–6 stars delivered an annualised total return (capital + income) of 11.3% in the year to March 2012, compared with 0–3.5-star assets, which returned 9.4% [9]. This differential was greater for buildings refurbished in the last five years, with corresponding values of 11.8% and 8.7 %, respectively. In the year to September 2013, the assets rated with NABERS energy at 4–6 stars yielded an annualised total return of 9.5% (cf: 7.7% for 0–3.5-star assets) [10].

2 ISPT and its approach to improving the energy efficiency of buildings

ISPT has over $9.2 billion of funds under management through investments in property. ISPT has a commitment to environmental sustainability in the property industry, and realises that to achieve this commitment, buildings' systems must be configured to be efficient and economical and kept in that condition by monitoring and adjustment. A datalogger downloads utility data daily from ISPT's 70 buildings, and annual engineering reviews identify potential improvements in the environmental efficiency of buildings in the property portfolio. To date, ISPT has prioritised improvements to energy efficiency, which has been followed by improvements to water, indoor environmental quality, and waste.

ISPT uses a SE–CS approach for upgrading the energy efficiency of its buildings. In this approach, the basic information such as the building systems brief and available documentation, as well as the history of maintenance and complaints, are collated and analysed. Then, the configuration and original setup of the building systems are reviewed and systematically questioned, and any viable opportunities to adjust them are implemented to bring the base systems to their ultimate configuration. Poorly performing systems or equipment may be upgraded or replaced. Tuning is then carried out on the adjustable parameters. In conjunction with the engineering approach, computer-modelling software is used to simulate potential improvements to energy efficiency. The software is a commercially purchased programme, Trace™ 700 energy and economy simulation and analysis (Trane, www.trane.com) [11]. The TRACE ("Trane Air Conditioning Economics") software includes an analysis of load, system, energy, and economics to compare the energy and financial impacts of building variables such as: building layout; heating, ventilation, and air conditioning (HVAC) systems; other electrical–mechanical systems; building utilization schedules; occupancy profiles; and climate. Alternative evaluations of proposed energy-saving concepts can be made based on different configurations of the systems.

3 Case study: 477 Pitt Street, Sydney

3.1 The building and its upgrades

The property at 477 Pitt Street is a 34-storey commercial office tower built in 1991 and is located within Sydney's CBD in the state of NSW. The tower offers 30 levels of office accommodation, ground floor foyer, lower ground retail, and two levels of basement parking, and has a leasable area of 48,000 m^2. The 10-storey wing contains offices as well as two floors of retail. The main period of refurbishment of the building with regard to electrical–mechanical systems, features, and equipment took place during various months in 2011 (Table 1). A complete replacement of the thermal plant was made and more modern high-efficiency chillers and equipment were installed. A major replacement/upgrade of the building management and control system (BMCS) was also made, including a comprehensive upgrade of the control strategies, such as optimising the operation of the new refrigeration plant and eliminating the potential opposition of cooling and heating in the HVAC system, resulting in substantial reductions in energy consumption. Low-temperature variable air volume (VAV) principles, variable volume flow in the chilled and condenser water system, air- and water-side static pressure reset routines, and optimum start/stop/lockout of all plant components were amongst the measures incorporated in the new BMCS functionalities.

Item	**Completion Date**
Replacement of refrigeration plant with high-efficiency chillers and state-of-the-art equipment.	01/03/2011
Provision of automatic isolating valves to tenant supplementary package air conditioners to enable adjustment to the condenser water system pump speed.	30/06/2011
Major replacement and upgrade of the building management and control system (BMCS)	08/08/2011
Re-engineering of the fan-assisted VAV air-side system, including recalibration of the air flow rates.	28/09/2011
Implement total air balance in air conditioning system and reduce opposition of heating and cooling.	28/09/2011
Comprehensive upgrade of the new BMCS routines and control strategies, particularly to enhance the operation of the new refrigeration plant and to eliminate the potential opposition of cooling and heating in the HVAC system.	05/11/2011
Upgrade of the air-handling plant controls to optimise the utilisation of the fan assisted boxes and minimise the use of electric heaters.	27/11/2011
Replacement of lights in stairs and some common areas to LED fittings with lower wattages.	30/12/2011

Table 1*. Summary of systems and equipment upgrades made for the office building at 477 Pitt Street.*

3.2 Improvements in NABERS energy ratings

Together, the improvements discussed above (Table 1) have improved the NABERS base building energy efficiency rating of this building from 3.6 stars (October 2011) to 5.1 stars (October 2012) to 5.3 stars (2013) (Table 2). The increase in rating from 3.6 to 5.3 stars equates to a 48% reduction in energy consumption. Reductions in electricity use have yielded savings of $530,000 per year for 2012–2013 compared with 2010–2011.

Period[§]	NABERS Energy*	Electricity (kWh/yr)	Gas (MJ)	Total Energy (MJ)
2007–2008	2.5 (2.7)	-	-	-
2008–2009	3.0 (3.3)	-	-	-
2009–2010	3.5 (3.5)	-	-	-
2010–2011	3.5 (3.6)	5,482,977 (19,738,717 MJ)	974,565	20,713,282
2011–2012	5.0 (5.1)	3,327,019 (11,977,268 MJ)	942,877	12,920,145
2012–2013	5.0 (5.3)	2,831,342 (10,1928,31 MJ)	932,224	11,125,055

§ NABERS energy ratings were assessed in October and relate to measured energy consumption in the preceding 12-month October–September period. * The formal (half-star interval) ratings stated are followed by exact ratings in parentheses.

Table 2. *NABERS ratings for the operation of the 477 Pitt Street building for energy consumption. The ratings and energy usage apply to the base building facilities and services only.*

3.3 Base building electricity use

Fig. 1 shows the monthly electricity consumption (in kWh) for the January–December years 2008–2014 for the base office building (i.e., without tenants' consumption). The monthly year-on-year differential in electricity use for 2008–2009, 2009–2010, and January–September 2010–2011 was very small to negigible. However, from October 2011, a large reduction in electricity consumption is seen, which resulted from the replacements and upgrades made during April–December 2011 (Table 1). Ongoing building performance tuning involving the BMCS to obtain the most efficient settings for the various electrical–mechanical systems has yielded further reductions in energy use.

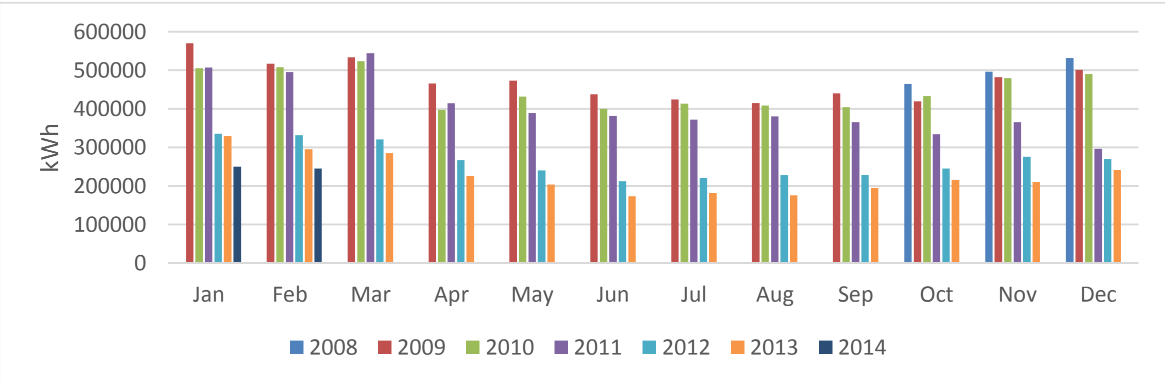

Figure 1*. Monthly electricity consumption (in kWh) for years 2008–2014 for the office building at 477 Pitt Street, Sydney. Note that the 2008 data include only months Oct–Dec, and 2014 data include only Jan–Feb.*

The usage types for electricity consumption are broken down in Table 3 (for January–December years, 2009–2013). The reduction in overall electricity consumption was 43.6% from 2011 to 2013. Energy reductions have been achieved across all usage types of base building central services and areas.

	2009	2010	2011	2012	2013	% change 2011–2013

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Tower Power	1,194,796	1,005,561	889,429	600,962	472,109	–46.9
Wing Power	538,806	470,890	424,298	273,309	222,892	–47.5
LG and G Floor Power	250,307	235,686	263,611	210,833	180,155	–31.7
Lifts/Elevators	437,826	463,198	442,310	415,970	387,536	–12.4
Chillers and Boilers	1,412,561	1,306,948	1,067,315	652,032	675,400	–36.7
HVAC cooling towers	985,009	982,657	854,982	542,147	350,535	–59.0
Retail Air Conditioning	306,367	360,627	349,133	119,635	121,904	–65.1
Car Park Exhaust	23,772	16,201	14,332	15,683	16,514	15.2
Car Park Lights Gates	224,296	250,513	220,777	143,173	92,650	–58.0
Fire Stairs and Services	303,168	302,978	318,434	202,422	214,707	–32.6
Total	5,676,908	5,395,259	4,844,621	3,176,166	2,734,402	–43.6

Table 3. *Annual electricity consumption (in kWh) for 2009–2013 by usage type for the 477 Pitt Street building.*

Fig. 2 presents the electricity consumption accounted for by chillers and boilers. A monthly year-on-year reduction in electricity use started in April 2011 (Fig. 2, top) but began in earnest in September 2011 and extended through all months of 2012 as a result of the replacement of the thermal/refrigeration plant in March 2011. The full effect of the March 2011 plant replacement therefore was not realised until September, when the upgrade to the BMCS (August 2011) was made. Fig. 2 (bottom), a plot of energy use data versus outside temperature, shows that electricity used for similar temperature conditions has reduced over time, and confirms that the reductions represent real improvements in system operating efficiency. Two trends are noted: one for before September 2011, and one for September 2011 onwards, reflecting the replacement of the thermal plant and subsequent upgrade to the BMCS. Most of the reduction has been for the warmer months (~90,000 kWh/month 2009–2013), with a smaller reduction for the cooler months (~35,000 kWh/month).

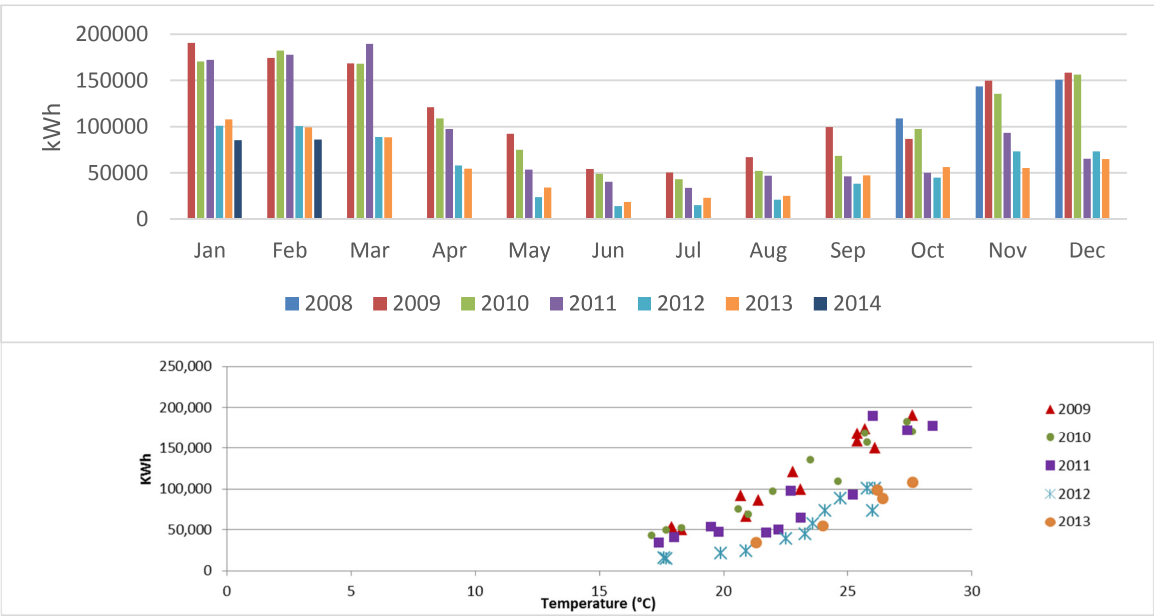

***Figure 2**. Chillers and boilers at 477 Pitt Street. (top) Monthly electricity consumption (in kWh) for years 2008–2014. (bottom) Monthly electricity consumption (in kWh) versus outside mean monthly maximum temperature for January 2009 to May 2013.The latest temperature data available are for May 2013.*

Fig. 3 presents the electricity consumption accounted for by the HVAC plant cooling towers. The monthly year-on-year pattern (Fig. 3, top) shows that a significant reduction in electricity use occurred starting in October 2011, a result of changes to the electrical–mechanical infrastructure including adjustable condenser water system pump speed (late June

2011), replacement of the BMCS (August 2011), and reconfiguration of the HVAC system including re-engineering the VAV air-side system and implementing a total air balance in the HVAC system (both September 2011). Another large monthly reduction in electricity consumption started in April 2013, the result of a tuning/optimisation phase of the HVAC system via the BMCS. Fig. 3 (bottom) shows three trends of electricity use data with respect to outside temperature: one for data up to and including September 2011, one for October 2011 to March 2013, and one for April–May 2013. The data therefore indicate two phases of reduced consumption, and show that the amount of electricity used for similar outside temperatures has reduced over time. Reductions in electricity use of ~35,000 kWh/month between the first and second data trends occurred for both warmer and cooler months.

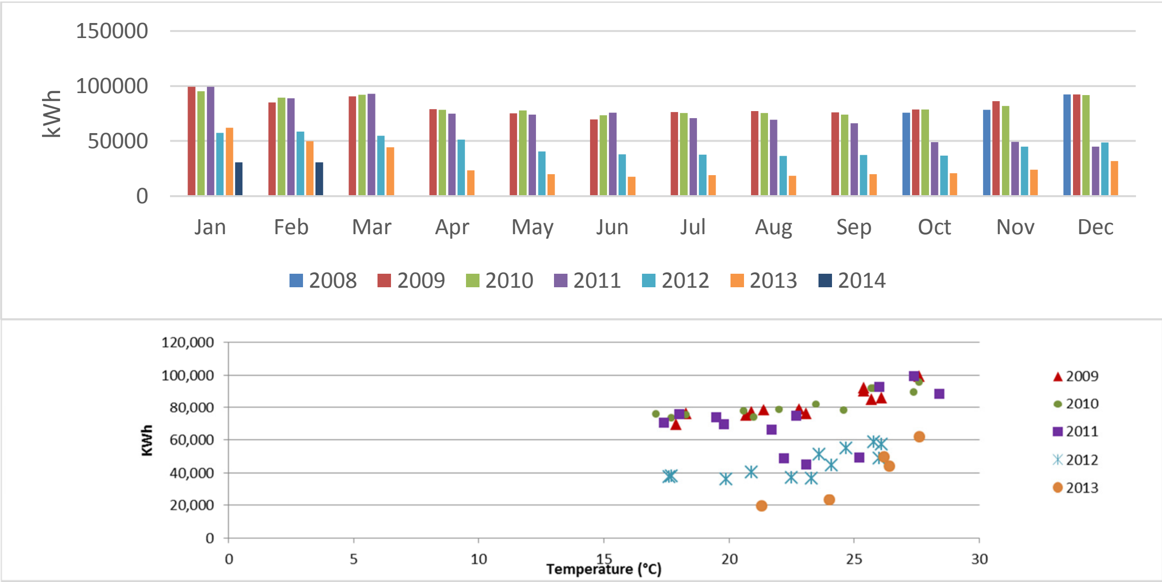

Figure 3. *HVAC cooling towers at 477 Pitt Street. (top) Monthly electricity consumption (in kWh) for years 2008–2014. (bottom) Monthly electricity consumption (in kWh) versus outside mean monthly maximum temperature for January 2009 to May 2013.*

Fig. 4 shows the pattern of monthly electricity usage for HVAC in the retail floors of the building with respect to outside temperature. Two trends are evident: one for up to and including November 2011 and one for December 2011 onwards, showing a marked improvement in the efficiency and consistency of retail HVAC since December 2011. This is a result of the upgrade of the new BMCS routines and control strategies and the effect on HVAC system efficiency, and the upgrade of the air handling plant controls (November 2011) (Table 1). The greatest increases in HVAC efficiency for 2010–2012 were for cooler weather.

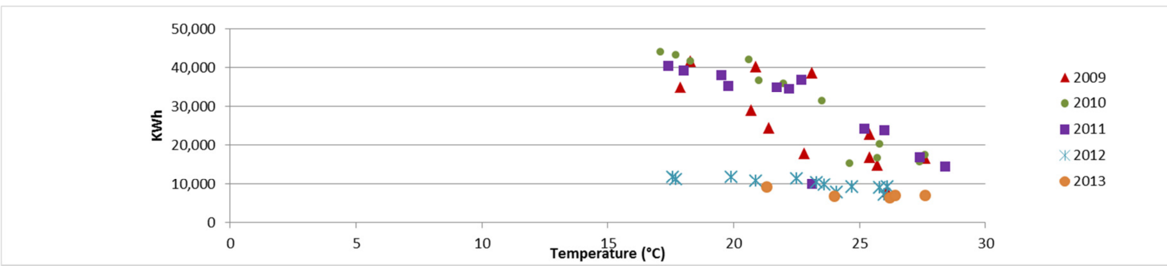

Figure 4*. Retail HVAC at 477 Pitt Street. Monthly electricity consumption (in kWh) versus outside mean monthly maximum temperature for January 2009 to May 2013.*

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4 Discussion and conclusions

This case study shows that the SE–CS approach used by ISPT has proved successful in improving the energy efficiency of the office building at 477 Pitt Street, Sydney, as measured by submetered utility consumption and corresponding NABERS ratings. Monthly electricity data for 2008 to 2014 show that the observed energy reductions have an excellent correspondence to the upgrades, replacements, and adjustments to electrical–mechanical equipment and controls, including the refrigeration plant, HVAC system, and the BMCS and its control strategies. In addition, the electricity data show that energy reductions have been achieved across all usage types of base building central services and areas. Furthermore, the data indicate marked improvements in the performance of both the thermal plant and the HVAC system.

It should be noted that the technological aspects of improving building environmental efficiency are just one facet of improving sustainability in the building/property industry. Technological aspects must be considered within commercial realities, such as the costs vs benefits of improvements and the protection and enhancement of investors' and owners' assets. Of importance is the relationship between environmental efficiency improvements and the NABERS rating tool [12], because certified NABERS ratings influence rents, the value of buildings, and the quality of tenants. ISPT's approach in improving the environmental efficiency of its buildings through engineering–computing represents the intersection of the application of technology, the enhancement of environmental sustainability, and the creation of value for all stakeholders, including investors, building owners, and tenants, and ultimately government and communities.

Acknowledgements

The generous cooperation of ISPT, and in particular Shahram Omidvar (Senior Portfolio Engineer), in supplying details of its methods and data for the building at 477 Pitt Street, Sydney, is gratefully acknowledged.

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Deep renovation of single family houses in Norway. Mapping of the most ambitious projects and lessons learned in them.

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Abstract: *This paper is based on work carried out in COHERENO, Collaboration for housing nearly zero energy (nZEB) renovation within the IEE Programme. The scope of the presented work was to map the most ambitiously renovated single family houses (SFH) in Norway and investigate the lessons learned in them. The main research questions are: What is the experience of the house owners and the professionals involved in the most ambitiously renovated SFH in Norway? What are the possibilities for enterprises to collaborate in the nZEB SFH renovation market? Both quantitative and qualitative research methodologies have been used. Only completed renovation projects were studied. The findings show that the house owners are ahead of the professionals when it comes to knowledge on ambitious renovation. A great share of do-it-yourself effort was laid down by the house owners. Contracts and quality assurance measures are seldom used, contrasting to the new built market.*

Keywords: Renovation, Energy, User experiences, Single family homes

Introduction

The Norwegian building stock consists of ca. 2.2 million inhabited homes (2011) and three quarters of these are small house buildings [1]. Of the Norwegian population, 80% live in single family houses, chained houses or duplex houses. The single family house is by far the most common type, accommodating 60% of the population [1]. Most of them were built after the Second World War and the majority in 1960-1990. These buildings are now ready for main renovation and large energy saving potentials can be realised if the ambitions are high enough. The EU 2050 Roadmap postulates extensive renovation on a deep renovation level of the European building stock as a prerequisite to reach the goals of a low carbon economy in the future [2]. According to a large European study by BPIE deep renovation is needed (i.e. ca. 70% reduction in energy use) and the renovation rate must be increased to 2.5-3% to reach the EU 2050 goals [3]. A Norwegian study identified a lack of profitability as the main barrier to energy efficiency in Norway, and that energy efficiency measures are most appropriately carried out simultaneously with other upgrading of the building [4]. The convergence between nZEB and cost-optimality is pointed out as a challenge also by BPIE [5]. The scope of the work presented in this paper was to map the most ambitiously renovated single family houses in Norway and to investigate the lessons learned in them.

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Method

This paper is based on the findings from both quantitative and qualitative research methodologies. Quantitative methodology in the form of a mapping of existing renovated SFH after a predefined set of criteria, and qualitative methodology in the form of open ended interviews and a workshop with representatives from the target group of the project[1]. The main research questions are: What kind of renovation is taking place in the most ambitiously renovated single family houses in Norway? What is the experience of the involved house owners and professionals? What are the possibilities for enterprises to collaborate in the nZEB SFH renovation market? As of yet, Norway has no official nZEB definition, excluding nZEB as a tracking criterion. The aim was therefore readjusted to find *the most ambitiously renovated single family houses in Norway*. For this purpose we developed the "nZEB radar", which allow us to cover a broader range of standards (e.g. passive-, plus- and low energy houses) close to the nZEB level. The radar has four sets of tracking criteria, illustrated by the four circles in figure 1, where the criteria get stricter the closer to the circles centre.

- Circle 1 (very dark green) the highest performance level, very ambitious, meeting the (assumed) nZEB criteria. Examples: plus energy houses, zero energy houses.
- Circle 2 (dark green) still a very ambitious level for renovation, not necessarily fulfilling all principles presented in BPIE's nZEB study. Examples: Passive House, Energy Performance Certificate (EPC) grade A.
- Circle 3 (light green) allows collecting examples of a wider range of projects, as project data bases and awardees. Examples: national database of model buildings, EPC grade B
- Circle 4 (very light green) includes projects that are on their way to nZEB renovation, with at least three measures from the list:
  - Wall insulation, U-value ≤ 0.22 W/m^2K (200mm insulation)
  - Roof insulation, U-value ≤ 0.18 W/m^2K (250mm insulation)
  - Super insulated windows, U-value ≤ 0.80 W/m^2K
  - Update of an old heating system (including boiler, pumps, etc.)
  - Mechanical ventilation with heat recovery
  - Integration of renewable energy sources, covering >50% of heat demand

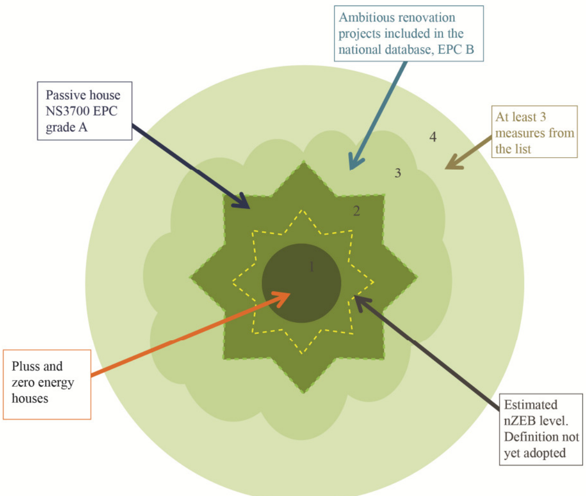

***Figure 1** The nZEB radar and criteria used for mapping of ambitiously renovated SFH in Norway.*

Telephone interviews were done with the house owners of the SFH that met the tracking criteria of the nZEB radar. The interviews were open ended, with guiding questions like: Which actors were involved in the renovation? What measures were carried out? What was

[1] Contractors, architects, consultants, financing and informing actors.

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your motivation for ambitious renovation? What is your experience with the renovation process? Three of the interviews were carried out with house owners in their homes.

Based on the findings from the interviews, a workshop with key actors was held, focusing on the possibilities for enterprises to collaborate in nZEB SFH renovation market. The workshop method enables detailed discussions on complex issues and problems. When challenged with specific tasks and questions, an interdisciplinary group can reach more reflected decisions and solutions to problems [6]. Using group dynamics, the participants reacted and built upon each other's responses. As moderators, we detected the most important barriers and opportunities for collaboration and quality assurance in the nZEB SFH renovation market.

Findings

Following the criteria defined by the nZEB radar we were able to compile a list of 33 completed SFH renovations in Norway by May 2014. However, during the telephone interviews we identified, and removed, houses that incorrectly had been listed to meet our criteria, leaving us with 26 houses. 13 of the 26 house owners were interviewed. We were not able to reach the other 13 house owners, despite repeated attempts via telephone. Hence, the mapping shows that there are 13 confirmed single family homes in Norway built in the period 1950-1990 that either received an EPC grade of A or B, a low-energy house certificate or a Passive house certificate. None of the identified houses met the criteria of circle one in the nZEB radar (zero or plus energy houses). Three houses met the criteria of the second circle (Passive house certificate or EPC grade A). 9 houses met the criteria of circle three (Listed in national databases, EPC grade B). 1 house met the criteria of circle four (3 measures from the list). The locations of the 26 identified houses are indicated in the map to the left in figure 2. The map in the middle shows the location of certified energy consultants in Norway[2]. The map to the right is a combination of the two, showing that there is a correlation between the location of projects and certified energy consultants.

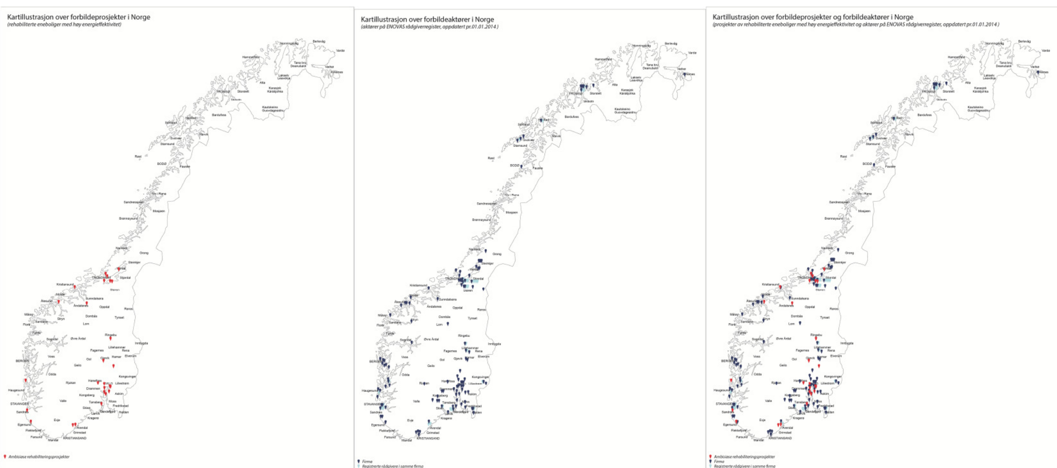

***Figure 2** Maps showing the location of the mapped ambitiously renovated SFH in Norway and the location of certified energy consultants.*

[2] Enova provides an overview over energy consultants with an exam from a passive house course. http://www.enova.no/radgivning/naring/kundenare-radgivere/radgiverregisteret/radgiverregisteret/77/96/?passivhustext=&type=&search=

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Several sources were used to identify the most ambitiously renovated SFH. The majority were found in the Norwegian EPC database[3] administered by the Norwegian Water Resources and Energy Directorate (NVE). Others were found through The Norwegian State Housing Bank (Husbanken) and Enova which provides low interest loans and funding schemes for encouraging energy efficiency in SFH respectively. A few SFH were identified through other SINTEF research projects and through frontrunner actors within the architect and energy consultant professions.

Interview findings

Two groups of house owners

The telephone interviews revealed two groups of house owners, one that did the renovation stepwise and the other that did it in one operation. The ambition level and the time frame of the renovation were the decisive factors for which group a project falls into. The two groups were of almost equal size. The first group included house owners that renovated their house over time and lived in their homes during the process. They made a typical step-by-step renovation, carrying out one room, building element or a part of the construction at a time. Within this group we identified a high level of do-it-yourself effort. The house owners covered the roles of several professions, depending on training, knowledge, and interest (i.e. architect, energy consultant, carpenter and excavator). The second group carried out the renovation works prior to moving in. Within this group we could see a slightly higher ambition level and a higher share of external professionals were hired in. Still, a high level of do-it-yourself effort was laid down by the house owners. We found that that the houses in this group were heavily stripped down, often leaving only the core construction, before rebuilding started. Also, within this group, extensions and/or reconstruction works to the original design was often carried out as part of the renovation works.

Personal interest in the field

A high degree of personal interest in the field of energy efficiency was common among all the interviewed house owners. There was a strong correlation between this and the high level of ambition. The majority of the house owners have a background from the building sector (consultant, architect or craftsman) or from energy, climate or environmental sectors. Two house owners were driven by personal interest. Several house owners expressed difficulties in finding entrepreneurs and craftsmen with sufficient knowledge in the field of deep renovation. Eight of the house owners had done almost all research themselves on available products and solutions to achieve the best possible result. Several of the house owners also stated that they had used extra time and effort to guide and see to that the craftsmen executed the detailing correctly so that the high level ambitions could be reached (e.g. on air tightness). The interviews revealed that the entrepreneurs often acted as consultants for the house owners, however in terms of knowledge on energy efficient renovation the house owners were ahead

[3] http://www.energimerking.no/

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of the professionals. In cases were energy consultants and architects were not engaged, the heating system supplier or ventilation supplier acted as energy consultant.

Motivation for deep renovation

In the final question of the interviews, the house owners were asked their personal motivation for deep renovation. Out of these responses, five basic areas of focus were identified; increased indoor comfort, low and stable heating costs, energy efficiency, need for extension or reconstruction, and need for upgrading. Seven house owners named better comfort as a motivation for the renovation. Five named stable or lower running costs as a motivating factor, while five named energy efficiency. Eight house owners named the need for an extension or rebuilding as triggering factors for the renovation. Six house owners named the need for upgrading of building components and elements that have met their life expectancy as motivation for their renovation. These findings comply with the findings reported by Enova in a study on making the Norwegian building stock more energy efficient [4].

Home visit and in-depth interview

An in-depth-interview with the house-owner and the energy consultant of one of the most ambitious renovation projects we found (EPC grade A) was done in the winter of 2014.

Figure 3 *Photos of the SFH originally built in 1989 and renovated to EPC grade A in 2012.*

The house owners, man and wife, had just retired from working life prior to the renovation works. They wanted a comfortable and practical home with all functions on one level for their future as seniors. The house owner had a strong interest in the field of passive houses, which fuelled the wish for ambitious renovation. The renovation process took two years from start to finish, and lasted longer and became more extensive than foreseen. The house owner planned to renovate the first floor, while still letting out the two apartments on the ground floor, which turned out impossible due to fire regulations, daylight requirements and the house owners' decision to integrate the basement floor in the heating system (water based, geothermal heat pump). The total energy consumption for the three households (main apartment on first floor, two on the ground floor) has been measured to 12.700 kWh per year or 70 kWh/m^2/year.

The main lesson learned from the process was the importance of testing the air tightness of the building envelope early in the process, enabling improvements without destructive measures. The first blow-door test showed a leakage number just over 3,6, and was carried out after all indoor finishing was done, which greatly compromised their chance of tightening the air leakages that were revealed. A combination of thermography and several blow-door

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tests helped to identify and improve the air leakages to achieve a leakage number of just over 1,0. The house owner also stressed the importance of having a good carpenter on the team, that understood the task and was flexible and creative on coming up with good solutions, and willing to adjust to the house owner's do-it-yourself efforts.

Workshop findings
The findings derived from the nZEB radar and the interviews were presented for 10 leading Norwegian actors on nZEB renovation of SFH as a basis for the workshop focusing on the possibilities as well as pitfalls for enterprises to collaborate in nZEB SFH renovation market. Leading questions were designed to identify corporative and technical challenges, as well as well functioning aspects, barriers and motivators within the renovating segment.

Lack of a holistic focus and cooperation
Findings from the discussions show that actors are not being responsible together for the end-result, leading to a lack of holistic perspective. Today the different area of responsibility is separated, leading to increased focus of maximizing profit and selling products gaining each trade, rather than focusing on the overall end result and gaining a common profit. Lack of insight in each other's trades stands out as barriers to reach a holistic renovation approach. In addition actors carry out work with blurry goals or no clear goals at all for the end result.

Distrust
Lack of knowledge, and providing work at a minimum level of quality, stand out as a barrier to build trust among the house owners. As an example, building joiners often focus on additional insulation, without taking into consideration the change of physics for the building, which raises the need of ventilation system to maintain a good indoor climate. Another barrier to increase level of trust among house owners, is little documentation and verification of the quality of the work carried out. There is not a culture for learning from own work to make improvements for the next.
Contracts and checklists
Lack of team work- and interaction contracts was identified. Collaboration between different craftsmen and entrepreneurs take place without clear roles and interplay. The sector seems good at contractual work, while they bother less when carrying out non-contractual work. Contracts are not mandatory, leading to less liability and poor quality assurance. Due to this, several of the leading actors in the workshop stressed the need for a technical regulation for renovation to lift quality assurance, collaboration and liability.

Conclusions
The mapping shows that there are just over 20 single family homes in Norway built in the period 1950-1990 that have received an energy label of A or B. Ambitious renovation of SFH is a niche in Norway so far. Findings show that entrepreneurs often acted as consultants for house owners, however in terms of knowledge on energy efficient renovation on a high ambition level, house owners were often ahead of the professionals. The success of ambitious renovation in the projects studied relied on the house owners' self-interest in the field.

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Comprehensive changes of the existing building were necessary in many of the projects studied, requiring temporary accommodation during intervention. In addition, a great share of do-it-yourself effort was laid down by the house owners. The main barriers for ambitious renovation were identified as; lack of interest and knowledge amongst actors influencing house owners in the planning process, lack of user-friendly and impartial channels guiding house owners through the renovation phase, and finding the right actors, products, funding and inspiration for possibilities in design. The challenge of finding actors with sufficient knowledge on deep renovation combined with house owners' high ambitions and good knowledge in the field causes distrust towards professionals. In combination with a culture for DIY in the SFH segment in Norway, this is likely a reason for the extensive do-it-yourself efforts. The main points from the workshop with leading Norwegian actors were summed up as:

1. Induct use of contracts and check-lists in rehabilitation project
2. There is a need for requirements or a technical regulation (TEK) for rehabilitation.
3. Events and workshops should be held to share knowledge and find collaborating partners

Acknowledgment
We would like to thank NVE for providing us with the insight into the Norwegian EPC database. We would also like to thank the house owners for opening their doors for us, literally, and sharing their renovation experience.

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Lessons from reality: examples of near zero energy dwellings in practice

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Abstract: *In the frame of the EPBD Recast, each EU Member State is establishing legislative actions to prepare the building sector and future building owners to the future nearly zero energy ambition level. However, there are architects and builders who do not wait for this strengthening, but decide to build nearly zero energy houses right now, in a hands on way. In this paper, 14 nearly zero energy dwellings are presented. They represent a diversity in construction type, typology, air tightness level, insulation level and heating system. The only technology they have in common is a mechanical ventilation system with heat recovery. The lessons that can be learnt from these dwellings are presented through a comparison between theoretical and real energy and comfort performance based on monitoring and surveying.*

NZEB concepts, energy consumption, indoor climate, occupants' perception

Introduction

In the frame of the Recast of the Energy Performance of Buildings Directive (EPBD) [1], each EU Member State has to develop a roadmap for the realization of the ambition to build only nearly zero energy buildings (NZEB) from 2021 on. Governments are establishing legislative and promotional actions to prepare the building sector and future building owners to this ambition level [2,3]. Furthermore, many research efforts have already been undertaken to develop new NZEB concepts [4,5]. Very often, the focus is on new, innovative technologies and the performance of these concepts is assessed with theoretical simulations. However, there are architects and builders who do not wait for this strengthening and these new technologies, but decide to build nearly zero energy houses right now, in a hands on way. So, by studying these dwellings in practice, not only their energy performance, but also the occupants' experiences in and perceptions of these dwellings, many lessons can be learned about the do's and don'ts of NZEBs that can be applied in future to build NZEBs.

In a research project BEP2020 [6], the reliability of Flemish energy labels as indicators for the real energy performance of low energy dwellings was analyzed together with the robustness of different energy saving measures. In this context, 72 recently built dwellings, among which 14 nearly zero energy dwellings, were analyzed for energy and comfort performance through calculations, monitoring and surveys. The concepts and the performance of the 14 nearly zero energy dwellings will be presented and discussed here.

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Firstly, the Flemish NZEB definition is presented, together with a description of the 14 nearly zero energy dwellings and of the analysis methods used (calculations, monitoring and surveying). Then the most important results on energy and comfort performance are presented and discussed. Finally, some conclusions are made.

Methodology

Definition of a near zero energy dwelling

As implementation of the EPBD Recast and in accordance with the standard EN 15459 (CEN 2007), as imposed by the European Commission, the Flemish Government officially defined a nearly zero energy residential building as a building with at least an energy performance level (E-level) of E30 or less. The E-level is the ratio of the yearly primary energy consumption for space heating, domestic hot water and auxiliary systems (fans, pumps) calculated according EN ISO 13790 for Brussels, and the yearly primary energy consumption for space heating, domestic hot water and auxiliary systems for a reference building with the same compactness (ratio of heated volume and heat loss area). At the introduction of the Flemish EPBD Regulation in 2006, the maximum E-level was set at E100 and now, a NZEB should have an E-level of E30 or lower, meaning that the overall yearly primary energy consumption of a dwelling should be 30% or less of what a dwelling with the same configuration could consume in 2006. All 14 dwellings presented here, have an E-level of E30 or lower. Some even have a negative E-level, meaning that they produce more renewable energy than they consume on a yearly basis for space heating, domestic hot water and auxiliary systems.

Description of the dwellings

Table 1 presents the main characteristics of the 14 dwellings and figure 1 gives a picture of 5 of these dwellings. The E-level ranges from E(-6) up to E28. As a low E-level can be achieved by focusing on energy efficiency or on renewable energy production, also the E-level without the impact of electricity production by photovoltaic panels is given, as this E-level represents the real energy efficiency of the building. The only technology all 14 dwellings have in common is a mechanical, balanced ventilation system with heat recovery (therefore not mentioned in the table). Apart from that, they represent different combinations of construction type, dwelling typology, insulation level, air tightness level, heat production system and renewable energy system.

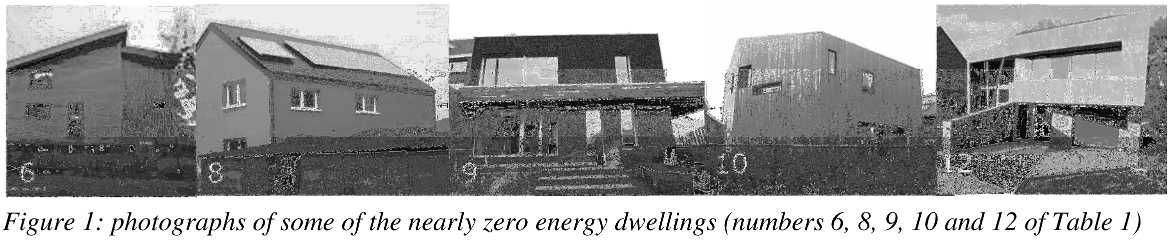

Figure 1: photographs of some of the nearly zero energy dwellings (numbers 6, 8, 9, 10 and 12 of Table 1)

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Table 1: Main characteristics of the dwellings

N°	Typo -logy	Constr type	Vol. m³	Floor area m²	E-level (-)	E-level without PV (-)	U_{mean} (W/m²K)	Air tightness n_{50} (1/h)	Heat prod.	Renew. energy syst.
1	D	WF	624	194	-6	50	0.15	0.41	None	PV
2	S	M	711	212	-2	23	0.15	0.27	None	TC+PV
3	D	WF	761	287	3	29	0.17	0.30	Electrical	TC+PV
4	D	M	1288	427	4	29	0.14	0.62	Woodstove	TC+PV
5	S	M	877	291	4	24	0.19	0.50	None	TC+PV
6	D	WF	764	209	5	18	0.19	0.29	HP A/W	TC+PV
7	D	WF	581	182	15	41	0.22	0.45	Woodstove	TC+PV
8	D	M	812	150	16	25	0.15	0.15	None	TC+PV
9	S	WF	599	164	17	41	0.15	0.55	Boiler	PV
10	D	M	-	227	20	38	0.34	-	HP G/W	PV
11	S	WF	531	164	22	52	0.22	0.38	HP A/A	PV
12	D	M	1175	370	27	27	0.39	0.97	HP G/W	None
13	D	WF	815	241	28	28	0.19	0.36	Wood gasific.	TC
14	D	M	-	262	28	-	-	-	Boiler	PV

Legend: Typology: S=semi-detached; D=detached / Construction type: WF=wood frame; M= brick cavity walls / Heat production: boiler=condensing boiler on gas; HP=heat pump; A/W=air-water HP; G/W=ground-water HP; A/A=air-air HP / Renewable energy systems: PV=photovoltaic panels; TC=thermal collector

Monitoring of energy consumption and indoor climate

For the energy consumption, the occupants noted weekly the energy meters for gas, electricity consumption and production and wood consumption during the year 2012. The indoor climate was monitored in winter and summer in each dwelling at least 2 weeks between November 2011 and April 2012 and at least 2 weeks between June 2012 and September 2012. Indoor air temperature, relative humidity and CO_2 concentration were monitored every 15 minutes in the living room and master bedroom. The outdoor air temperature, vapour pressure and solar radiation were measured in one central location in Flanders.

Survey of the building occupants

Occupants were surveyed for their behavior and their perception of the energy and comfort performance during winter and summer. Their presence in the house and their habits of opening windows, using the ventilation system and setting off the heating system during absence or night time were surveyed. For their perception of the energy and comfort performance, questions were asked on the height of their energy bill and on their perception of the general thermal comfort in winter and summer, specific thermal comfort in living room and bedroom and their general perception of the indoor air quality and the ventilation system.

Evaluation criteria for indoor climate

Thermal comfort was evaluated by means of the average indoor air temperature and standard deviation, and for the summer period also the maximum indoor temperature. The comfort

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zone is based on ISO 7730(2005) and is set in winter at 20°C-24°C for the living room and 18°C-22°C for the bedrooms. In summer, a comfort zone of 23°C-26°C is used for both room types. The indoor air quality (IAQ) is evaluated by means of the CO_2 concentration based on EN 13379 which defines four IAQ levels (IDA1 to IDA4) based on the difference between CO_2 concentration indoors and outdoors: IDA1 (< 400ppm above outdoor level, high quality), IDA2 (400-600ppm above outdoor level, medium quality), IDA3 (600-1000ppm above outdoor level, moderate quality) and IDA4 (> 1000ppm above outdoor level, low quality). For the outdoor level an average of 350ppm is used. For a good IAQ, at least IDA2 level should be aimed for. Furthermore, the measured results for thermal comfort and IAQ are compared with the perceived indoor climate by the occupants.

Results and discussion

Energy consumption: comparison of calculations, measurements and perception

As shown in table 1, some dwellings (1,7,9,10,11) need solar panels to reach the NZEB-level (E-level < 30), whereas the other dwellings reach already the NZEB-level without the use of solar panels (E-level without PV < 30). This means that for the latter the dwelling concepts focus more on improving the energy efficiency of building envelope and heating system. This can also be seen in figure 2 that presents the measured overall energy consumption in kWh per m² floor area as a function of the 'E-level without PV'. This energy consumption is the actually consumed energy and includes also the self-produced electricity by the PV panels.

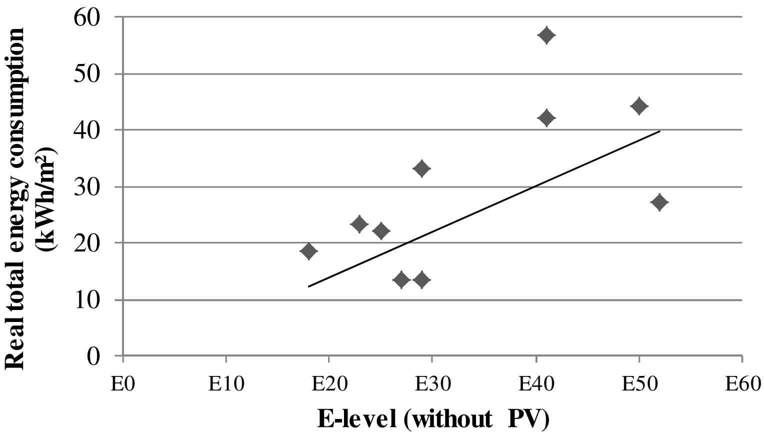

Figure 2: real energy consumption (in kWh/m² floor área) as a function of the E-level without PV

As the figure shows, the relation between 'E-level without PV' and real energy consumption is more or less linear. However, on individual dwelling level, the E-level as such cannot predict the real energy consumption, as also the occupants' behavior has an impact and can lead to quite differing energy consumptions between dwellings with the same E-level. For instance, comparing both dwellings with E-level E29 reveals that dwelling 4 has an energy consumption of 33 kWh/m² due to its wood consumption by the woodstove and its higher electricity consumption, whereas dwelling 3 has an energy consumption of only 13 kWh/m² due to its electrically post-heating of the ventilation air if necessary.

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Asked for the perception of their energy costs, 8 families perceived them as low, 5 families did not answer this question and 1 family perceived them as high. This last answer could seem somewhat surprising, since the latter lives in dwelling 12 having neither PV panels nor a thermal collector, but nevertheless only an energy consumption of 14 kWh/m² (5007 kWh in total). But due to the absence of PV panels, this household has the highest non-renewable electricity consumption, which has an impact on their electricity bill.

Thermal comfort: measurements and perception

In winter, most dwellings had an indoor air temperature in the living room within the comfort zone, except for two dwellings. However, when comparing measured and set temperature, only five dwellings had a measured temperature (± standard deviation) that approximated the set temperature. Nevertheless, the occupants of only two dwellings did not perceive the winter situation as comfortable. Surprisingly, these were not the dwellings outside the comfort zone and in only 1 of these dwellings, the measured temperature deviated from the set temperature. For the bedrooms, three dwellings had a measured air temperature outside the comfort zone (two below and one above comfort), but nevertheless in the surveys all occupants (absolutely) agreed that the bedrooms were comfortably warm. So, globally, it could be concluded that the thermal comfort in winter was satisfying in almost all 14 dwellings.

In summer, the situation was somewhat different. Table 2 gives the mean indoor temperature ± standard deviation and the maximum temperature during summer in the living room and master bedroom and the occupants' perception of the general summer comfort and the thermal comfort in the living room and bedroom. The maximum temperatures that are above the comfort zone and the negative perceptions are marked in bold.

Table 2: thermal comfort in summer in living room and master bedroom

	Measured air temperature (°C)				Perceived summer comfort		
	Living room		Bedroom				
N°	Mean temp. ± stand.dev.	Max. temp	Mean temp. ± stand.dev.	Max. temp	General	Living room	Bedroom
1	22.5±0.8	25.0	21.6±0.6	22.7	**Not good**	**Not good at all**	**Not good at all**
2	22.5±0.8	25.3	22.7±0.9	**26.1**	Good	Neutral	Neutral
3	25.6±1.4	**28.8**	25.5±1.2	**27.7**	Good	Good	Good
4	23.9±0.4	24.9	25.0±0.4	**26.2**	Very good	Good	Good
5	23.3±0.7	25.7	23.3±0.7	24.5	Neutral	**Not good**	**Not good**
6	23.0±0.8	24.9	23.1±0.5	24.9	Very good	Very good	Very good
7	23.7±0.8	**26.4**	21.4±1.0	23.9	Good	Neutral	Very good
8	25.8±0.6	**27.0**	25.7±0.5	**26.7**	Good	Good	Good
9	24.9±0.9	**27.1**	24.5±0.9	**26.8**	Good	Good	Very good
10	23.9±0.5	25.3	24.0±0.5	24.7	Good	Good	Good
11	23.1±1.4	**29.0**	21.3±0.8	23.0	Good	Neutral	**Not good**
12	25.0±0.8	**27.1**	24.1±1.1	**26.2**	Very good	Very good	Very good
13	24.9±0.8	**27.3**	24.1±0.9	**26.8**	Good	Good	Good
14	22.8±0.5	23.9	21.0±0.8	22.2	Good	**Not good**	**Not good**

Compared to the winter, the dissatisfaction with the thermal comfort was higher in summer (4 dwellings with a negative perception), and in 7 living rooms and 7 bedrooms air temperatures above 26°C were measured. However, as table 2 shows, there is no relation between the dissatisfaction and the measured temperatures: the dwellings in which the occupants complainted about the thermal comfort were not the dwellings that had higher maximum temperatures nor had these dwellings high fluctuating temperatures. And although in the overall group of 72 dwellings, dwellings in wood frame construction had in average a higher indoor air temperature in summer than dwellings in massive brick, this tendency could not be observed among the 14 nearly zero energy dwellings. Nor was there a relation with the presence or absence of solar shading.

So with regard to thermal comfort, it can be concluded that based on the measurements and on the surveys, the thermal comfort is rather good in all dwellings, although slightly better in winter than in summer. Nevertheless, there remains the variance in comfort perception among individuals, which makes it hard to guarantee absolute thermal comfort in dwellings.

Indoor air quality: measurements and perception

During winter, the CO_2 concentration was measured in 7 living rooms and 4 master bedrooms. For all living rooms, the CO_2 concentration was within IDA2-level during more than 60% of the time and for 6 out of 7 even during more than 80% of the time. Only for 2 dwellings (7,13), IDA4 was reached in 3% of the time. So generally, the IAQ in the living rooms was satisfying. However, in the bedrooms, the measured IAQ was less positive, since 2 bedrooms reached IDA2 for less than 30% of the time and reached IDA4 during even 10-20% of the time. However, none of the occupants complainted about the IAQ in the survey.

During summer, the CO_2 concentration was measured in 13 out of 14 master bedrooms and the IAQ results were not so positive. Overall, only 52% of the time IDA1 or IDA2 was reached, whereas 37% of the time IDA3 was reached and even 12% of the time IDA4. When looking at the habits of the occupants in the dwellings with the worst results, it appeared that the ventilation rate in most of these dwellings never changed (neither manually nor automatically) and some of the dwellings did not have windows that could be opened or occupants never opened windows for extra ventilation, as they were taught by the installer or the architect that with a balanced ventilation system, windows should be kept closed, ever. This ignorance of how to correctly use a balanced ventilation system and when (not) to open windows was also noticed among the occupants of other monitored dwellings.

Conclusions

Looking at the concepts of the 14 dwellings, it is clear that nearly zero energy dwellings can be realized in many ways, either by focusing on energy efficiency, on renewable energy systems or on both and even without highly innovative technologies. Nevertheless, in moderate climates, balanced ventilation with heat recovery combined with a good air tightness is indispensable for a nearly zero energy dwelling to reduce the ventilation heat losses. The indoor comfort analysis showed that thermal comfort remains difficult to assess by means of measurements, due to the differences in preference between individuals. There is a higher risk for overheating in highly insulated houses, but the perception might differ from what is measured (perception better or worse than what is measured). With regard to IAQ, bedrooms remain the weak point for a ventilation system (for all types of ventilation systems, as the analysis of the 72 dwellings showed), but it was also noticed that most occupants did not perceive the IAQ as bad. Nevertheless, there is a clear need to teach occupants (and architects and installers) how to correctly use a balanced ventilation system and how and when to interact in the ventilation of a dwelling by means of opening windows. A balanced ventilation system is designed from a hygienic viewpoint, to provide good IAQ without excessive heat losses, and therefore in winter, opening windows should be avoided to not shortcut the heat recovery. It is however not designed to provide a cooling effect through peak ventilation. Cooling in a moderate climate can be realized by opening windows or by integrating a ground pipe for precooling the ventilation air, especially at cooler moments during night or in the morning.

So as a global conclusion, it can be stated that nearly zero energy dwellings are not a utopia anymore, but are already a reality. However, when designing such a building, enough attention should be paid to the occupants, both on what their sensibilities are and on teaching them how to interact with this building.

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Session 124:

Which should be the contribution of life-cycle assessment in NZEB?

Chairperson:

Tenorio, José Antonio

Responsable de la Unidad de Calidad en la Construcción. Instituto de Ciencias de la Construcción Eduardo Torroja. CSIC

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EnerBuiLCA: life cycle assessment for energy efficiency in buildings

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4. LNEG, Lisboa, Portugal
5. NOBATEK, Anglet, France

Abstract: *Reducing the huge environmental impacts caused by buildings- direct energy consumption and embodied energy of materials- needs a broader application of LCA. However this meodology is seen as too complex and time-consuming for being integrated in their daily work. There is a need to bring this methodology closer to a broad public not necessarily familiar with the LCA methodology.*
The EnerBuiLCA project (funded by the ERDF through the Interreg IV B programme) has developed a user friendly tool associated to an environmental information database of construction products developed with available Environmental Product Declarations (EPD). This tool has been tested on 20 pilot studies. It calculates the building´s primary energy consumption and the Global Warming Potential measured in CO_2 equivalents, allowing an initial screening of the hotspots throughout the building´s life cycle. Tool´s limitations are sought to be overcome in other research projects such as URBILCA.

Key words: Buildings, LCA, EPD, energy efficiency

Introduction

Two major global concerns have been identified: reducing energy consumption and the amount of associated Green House Gas emissions (GHG hereafter). In this context, the European Commission adopted a European Strategic Energy Technology Plan [1] in which a clean, efficient and low-carbon energy technology scenario for Europe is envisaged for 2020 by means of a triple 20% objective: GHG emissions reduction from 1990 level, increase of renewable energy sources in the energy mix and primary energy consumption reduction to improve energy efficiency. The European Union has also identified potential for reduction in energy consumption especially in energy intensive sectors such as construction, which will contribute to improving energy efficiency.

Buildings are responsible for 40% of energy consumption and 36% of CO_2 emissions in the European Union [2]. The Directive on energy performance of buildings [3] and its recast dated May 2010 [4] is the main legislative instrument at EU level to achieve energy performance in buildings, and therefore achieve the EU´s climate and energy objectives. Under this Directive, the Member States must apply minimum requirements as regards the energy performance of new and existing buildings and ensure the certification of their energy performance.

Measures to improve energy performance in buildings introduced through this Directive in member states legislation, focus in minimizing direct energy consumption to supply heating and cooling, hot water and lighting demands during the building's use phase. However, energy consumption associated to other phases of the building´s life cycle such as the production of construction materials and other indirect impacts are still overlooked. In this regard, studies have shown that the amount of embodied energy in construction products can vary between 9 and 46% of the overall energy demand of the building´s service life in low energy consuming buildings and between 2 and 38% in conventional buildings [5]. A more global and realistic approach is therefore required to quantitatively evaluate the energy consumption and associated environmental impacts of buildings 'from the cradle to the grave', and effectively improve their life cycle energy efficiency.

According to the European Commission [6,7,8, 9], currently the Life Cycle Assessment (LCA) methodology constitutes the most appropriate framework to adequately assess the environmental impacts of any kind of activity, product or service throughout its life cycle. However, the application of this methodology to the construction sector is quite complex and needs to be adapted through appropriate tools to fit the particularities of the buildings and the relative lack of information throughout the sector. LCA is therefore considered as a versatile and useful tool for reducing the energy consumption and associated GHG emissions of the construction sector and establishing the most appropriate environmental improvement measures from a global perspective [10, 5].

The application of LCA to buildings, allows considering the environmental impact of all stages of their life cycle, including the product, construction process, use and end of life stages. At present, the current legislative framework is leading to the minimization of the environmental impacts associated to the use phase of the building, increasing therefore the relative weight of the remaining phases of the life cycle of the buildings.

The EnerbuiLCA project

The EnerBuiLCA European project, funded through the Interreg IV B programme aimed at fostering sustainability in the construction and refurbishment of buildings used either for housing or industrial uses. In so doing, a tool for the quantitative assessment of direct and indirect energy related impacts of buildings in Spain, the South of France and Portugal was developed based on the LCA methodology. The application of the tool allows the development of the appropriate strategies for reducing energy related impacts throughout the building´s life cycle, from materials production, building construction, use and maintenance to building refurbishment, thus promoting the development of the new `Life Cycle Zero Emission Buildings ´standard´[11].

Other project objectives included the training amongst the project beneficiaries- including any professionals related to the building sector- in the use and application of LCA for designing energy efficient buildings and raising awareness on the need for and opportunities to develop more sustainable buildings.

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The main results of the project, other than the EnerBuiLCA tool for the life cycle assessment of buildings, included the creation of a Thematic Network on LCA and energy efficiency in buildings, a database of representative construction systems for the SUDOE area and 20 pilot studies.

Methods

The EnerBuiLCA tool is accessible through the project website to all users registered within the Thematic Network, and is based on the LCA methodology as described in ISO 14040 and ISO 14044 standards [12, 13]. Technical specifications and calculation methods contained in EN 15643-1 [14], EN 15643-2[15], EN15804 [16] and FprEN 15978 [17] have also been considered in the development of the tool.

Life cycle assessment (LCA) addresses the environmental assessment of goods and services through their life cycle. The life cycle of a product is defined as the complete supply-chain of the product plus its use and end-of-life treatment. The standardized phases of an LCA include goal and scope definition, Life Cycle Inventory (LCI), Life Cycle Impact Assessment (LCIA), and the interpretation of results.

System boundaries

Taking into account the EnerBuiLCA's objectives, the software tool considers the building's **product, construction and use stages**, leaving the end-of-life stage out.

Database

Carrying out a LCA of complex products, such as buildings, is difficult and entails collecting a huge amount of quantitative data related to its individual life-cycle phases (LCI). The LCI of the production phase, due to the fact that hundreds of different products are used in the construction of a building, is foreseen as the most difficult and time-consuming to complete. Many databases have been developed by different commercial and industry data base providers in the last decades to facilitate this phase [18, 19]. However these databases offer a limited amount of construction-related datasets. The development of complete, up-to-date, flexible and free-cost LCI database was therefore considered necessary from the outset and is one of the main results of the EnerBuiLCA project.

The strategy followed for the development of this database involved the identification and the characterization of the main representative construction systems for Spain, France and Portugal and gathering information from available Environmental Product Declarations (EPD) of construction products under different ecolabelling schemes such as DAPc, Umwelt Deklaration, the International EPD System etc [20, 21, 22]. In doing so, three different standard databases were developed:

- 1 Construction products database including 72 different products;

- 1 EPDs database including 169 entries with information on primary energy (MJ) and kg of CO_2 equivalents;
- 3 Construction systems databases specific for each country including 18 representative systems for Spain, 20 for France and 11 for Portugal. These systems are defined by standard products which in turn are respectively related to an EPD.

A generic database including information on energy sources and transport has also been integrated into the tool.

To become part of the EPD database, EPDs had to be registered with a programme compliant with ISO 14025; declare primary energy and CO_2 equivalents information and, as a minimum, declare the information from the product stage.

The environmental product database can include further information on products as its use increases. Only EPDs that have gone through a validation process integrated within the tool would be susceptible for becoming part of the standard database.

Pilot Studies

The tool was tested on 20 different pilot studies of real existing buildings in the three countries. These were selected following a multi-criteria analysis which included: geographical and climatic area, type of building and structure, construction systems used and data availability. The pilot studies were identified, characterized, and quantified in the framework of the project and the information gathered used as inputs to the tool. Energy simulations were developed to obtain information on final energy consumption. These results were also used as inputs to the tool and to obtain the energy certification according to each country´s relevant procedure. After the application of the tool to each pilot study, LCA results on Global Warming Potential (kg CO_2 equivalents) and Primary Energy (MJ) indicators for the product, construction and use phases were obtained.

User´s interface and needs

In order to create and evaluate a project, the designer needs to (1) define the project and (2) the product stage followed by (3) the construction and (4) use stages in line with the system boundaries established for the project. Having done this, the designer will be able to calculate the results (5) and generate the associated excel spread sheet with environmental results and graphic information (6).

The designer in step (1) can choose to evaluate a building to be built or refurbished and following the selection of the Country in which the building is located- which will determine the construction systems and generic databases- continues defining the project with information such as: geographic and climate area, type of building, built and habitable floor space areas, service life etc.

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Having done this, the designer will be able to move on to (2) by defining the construction systems integrating the building, the categories of which include façades, roof, dividing walls, vertical and horizontal structures. The measuring unit for each of these categories is m^2 except form the vertical structures which are defined by the units of the products integrating them. Each product forming each system is associated to an EPD. The tool is programmed to adapt the declared unit to the building´s functional equivalent in line with guidelines contained within EN 15978 [17].

Since the product and construction system databases currently contain limited amount of information, the designer at this stage will be able to select a system from the standard database and will also be able to modify the information associated to it to adapt it to the real scenario under study. Besides this, the user will also be able to create new products or construction systems.

Construction stage (3) implies the definition of some values relating to the construction of the building. The tool incorporates default values on electricity (24,23 MJ/m^2 construction system) and diesel (23.4 MJ/ m^2 construction system) consumption from on-site machinery, amount of waste generated on site (120 kg/ m^2construction system) and its transport distance (50km) to the treatment facilities. The transport distances of the products included in the constructive systems from the factory gate to the building site (50km) are defined in step (2) when defining the construction systems. These default values were extracted from real data from a previous research project [23] and can be changed by the user if in possession of this information.

The user has to introduce the information on the energy consumption of the building during its use phase (4) which he would have previously obtained from a relevant simulation tool. The user can choose to introduce the information by type of use (heating, cooling, DHW and lighting) and source of energy associated to each use (renewable or non renewable including electricity, natural gas and diesel oil) or just by the source of the energy. The operation of the related equipment and services of the building has not been considered within the system boundaries neither have water demand, users' mobility, consumable products, solid waste, etc. Building maintenance, repair, replacement and refurbishment processes are also considered at the use stage. Necessary maintenance during a product´s service life is extracted from the product EPD.

Having done this the user is able to obtain real-time information on energy consumption and the associated GHG emissions of the evaluated building to be built or refurbished (5 and 6) (Figure 1).

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	Consumo de energía primaria					Huella de carbono		
RESULTADOS DE IMPACTO	MJ total	*MJ Renovable*	*MJ No renovable*	MJ total/año	MJ total /m^{2}año	kg CO2 eq	kg CO^2 eq /año	kg CO^2 eq /m2año
Producción (A) TOTAL	7.05E+06	--	--	1.41E+05	8.09E+01	8.37E+05	1.67E+04	9.61E+00
Fase producción (A1-A3)	7.05E+06	--	--	1.41E+05	8.09E+01	8.37E+05	1.67E+04	9.61E+00
Construcción (A) TOTAL	3.21E+05	*2.40E+04*	*2.97E+05*	6.42E+03	3.23E+00	1.87E+04	3.74E+02	1.88E-01
Transporte hasta puesta en obra (A4)	1.12E+05	*1.37E+02*	*1.12E+05*	2.24E+03	1.12E+00	7.33E+03	1.47E+02	7.37E-02
Proceso de construcción (A5)	2.09E+05	*2.39E+04*	*1.85E+05*	4.19E+03	2.10E+00	1.14E+04	2.27E+02	1.14E-01
Uso (B) TOTAL	4.42E+07	*1.32E+07*	*2.70E+07*	8.83E+05	5.07E+02	2.08E+06	4.16E+04	2.39E+01
Uso de energía operacional (B6)	4.02E+07	*1.32E+07*	*2.70E+07*	8.05E+05	4.62E+02	1.54E+06	3.07E+04	1.76E+01
Substitución (B4)	3.93E+06	--	--	7.87E+04	4.51E+01	5.43E+05	1.09E+04	6.23E+00
TOTAL CICLO DE VIDA	**5.15E+07**			**1.03E+06**	**5.91E+02**	**2.94E+06**	**5.87E+04**	**3.37E+01**

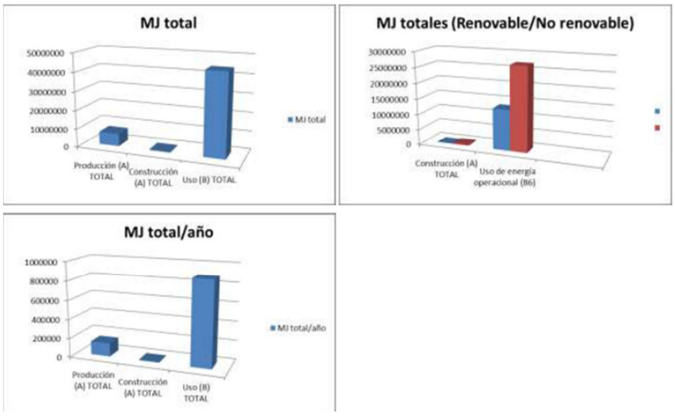

Figure 1: Sample of impact and graphic information generated from the tool in an excel file

The needs of the potential users of the tool were taken into consideration through the analysis of the results of surveys undertaken to the users registered to the thematic network (currently 1,012) before and after publishing the tool. A survey amongst the 65 users that have created a project with the EnerBuiLCA tool since its publication has also been undertaken after project implementation.

Results of the application of the tool

This paper presents information on the 20 pilot studies and the results for the Primary Energy indicator after the application of the EnerBuiLCA tool. Besides it summarises the results of the survey undertaken to the 65 users that created a project with the tool.

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Building description							LCA results Primary energy (MJ/m2 climatized area*year) Percentages			
nº	**Type of Building**	**Country**	**CA**	**Materials assessed**	**ES Tool**	**EC**	**Product**	**Building**	**Use**	**Total**
New Buildings built										
	Housing block						2,90E+01	3,02E+00	7,94E+02	8,26E+02
1	(residential)	Spain	C2	Envelope+structure	Lider y CalenerVyP	C	3,5%	0,4%	96,1%	100,0%
	Housing block						3,02E+01	4,78E-01	6,82E+02	7,13E+02
3	(residential)	Spain	C2	Envelope+structure	Lider y CalenerVyP	C	4,2%	0,1%	95,7%	100,0%
	Housing block						2,97E+01	3,95E+00	1,72E+02	
4	(residential)	Spain	D3	Envelope+structure	CALENER VYP	C	14,5%	1,9%	83,6%	100,0%
	Single family house						**1,51E+02**	**6,50E+00**	**4,23E+02**	
5	(residential)	Spain	D3	Envelope	CALENER VYP	B	**26,0%**	**1,1%**	**72,9%**	100,0%
	Offices and laboratories						**8,09E+01**	**2,90E+00**	**2,99E+02**	
6	(services)	Spain	D3	Envelope	CALENER GT	A	**21,2%**	**0,8%**	**78,1%**	100,0%
	Offices and laboratories						-	-	-	
7	(services)	Spain	B4	Envelope+structure	CALENER VYP	D	18,2%	0,5%	81,3%	100,0%
	Health centre						-	-	-	
8	(services)	Spain	A3	Envelope+structure	CALENER VYP	C	0,9%	8,8%	90,3%	100,0%
	Nursing home						-	-	-	
9	(services)	Spain	C4	Envelope+structure	CALENER VYP	C	7,0%	0,4%	92,6%	100,0%
	Secondary school						1,55E+01	5,50E+00	5,14E+02	5,35E+02
10	(services)	Spain	C1	Envelope + geometry	Autodesk Ecotect Analysis 2010	-	2,9%	1,0%	96,1%	100,0%
							1,52E+02	**1,50E+01**	**2,03E+02**	3,70E+02
11	Industrial	Spain	C1	Envelope+structure+geometry	Design Builder	-	**41,1%**	**4,1%**	**54,9%**	100,0%
							3,79E+01	1,28E+01	7,30E+02	7,80E+02
12	Offices (services)	Spain	C1	Envelope + geometry	Autodesk Ecotect Analysis 2010	-	4,9%	1,6%	93,5%	100,0%
	Offices and laboratories						**9,97E+01**	**2,90E+00**	**2,63E+02**	3,65E+02
13	(services)	France	H2C	Envelope+structure	CLIMAWIN		**27,3%**	**0,8%**	**71,9%**	100,0%
	Single family house						**1,67E+03**	**7,37E+00**	**2,80E+03**	4,48E+03
14	(residential)	France	H2C	All except lighting	Pléiades Comfie		**37,3%**	**0,2%**	**62,5%**	100,0%
	Housing block						**1,37E+02**	**3,43E+00**	**3,84E+02**	5,24E+02
15	(residential)	France	H2C	Envelope+structure	Alcyone + Pléiades Comfie		**26,1%**	**0,7%**	**73,2%**	100,0%
	Single family house						9,31E+04	1,46E+04	2,40E+06	2,51E+06
16	(residential)	Portugal	I1 ; V2 Norte	-	DesignBuilder	A+	3,7%	0,6%	95,7%	100,0%
	Offices and laboratories						2,44E+05	1,96E+05	4,63E+07	4,67E+07
17	(services)	Portugal	I1 ; V2	-	DesignBuilder	A	0,5%	0,4%	99,1%	100,0%
							1,35E+06	1,41E+05	7,41E+07	7,56E+07
18	Hotel (services)	Portugal	I2 ; V1 Norte	-	DesignBuilder	C	1,8%	0,2%	98,0%	100,0%
							2,60E+04	1,94E+04	4,88E+06	4,93E+06
19	Nursery (services)	Portugal	I2 ; V2 Norte	-	DesignBuilder	C	0,5%	0,4%	99,1%	100,0%
	Education centre						2,58E+05	1,87E+05	5,68E+07	5,73E+07
20	(services)	Portugal	I1 ; V2	-	DesignBuilder	D	0,5%	0,3%	99,2%	100,0%
	Single family house						2,96E+01	7,20E+00	3,49E+02	3,86E+02
21	(residential)	Portugal	I1, V2	Envelope	RCCTE	A	7,7%	1,9%	90,5%	100,0%
Refurbishments										
	Housing block (residential+ offices)								1,15E+03	1,15E+03
	Pre refurbishment	Spain	C2	-	Lider y CalenerVyP	E			100,0%	100,0%
2	Housing block (residential+ offices)						1,68E+00	2,37E-01	8,67E+02	8,69E+02
	Post refurbishment	Spain	C2	Envelope+structure	Lider y CalenerVyP	D	0,2%	0,0%	99,8%	100,0%
	Refurbishment savings						**24,78%**			

Table 1: Case studies information and Primary Energy Indicator results after the application of the EnerBuiLCA tool
Notes: CA= Climatic area, ES Tool= Energy simulation tool, BA= Built area, HFA= Habitable Floor Space, EC= Energy Certification

Wide heterogeneity amongst the Primary Energy Indicator results associated to each phase can be observed. According to the results, the amount of embodied energy in construction products can vary between 0.5% (lowest value for case study number 19) and 41% (highest value for case study number 11) of the overall energy demand of the building´s service life. Despite the fact that the building´s product phase normally represents a 30% of the overall energy demand, only 6 out of the 20 pilot studies evaluated, representing a 30% of the sample, showed results close to this value ranging from 21% to 41% (numbers 5, 6, 11, 13, 14 and 15). This is due to simplifications undertaken when characterizing the construction systems in the product stage which mainly include those involved in the envelope of the building. Since the objective of this exercise was to test the tool, these simplifications were considered appropriate. These percentages of primary energy from the building´s product phase regardless of their contribution to the building´s final energy demand are not considered in the energy certification of the building.

Table 1 also shows the results of a refurbished building (number 2). When comparing the results prior and post refurbishment, it can be observed that the energy demand from the use phase reduces producing a 24% global energy savings.

Results obtained from the surveys undertaken to the users of the tool showed that 50% of the respondents came from an academic or research backgrounds linked to architecture whilst the remaining 50% were distributed amongst professional associations, construction products producers and engineering companies. 50% of the respondents had previously used the LCA methodology for the assessment of buildings, construction systems or products by means of the SimaPro software or other tools to develop EPDs. SimaPro users had made use of it in an academic context.

As for the limitations of the tool, 66% of the respondents reported the tool lacked environmental information to appropriately define the product phase and found the input to define the use phase limited. 88% found information limitations to define the construction phase, particularly relating to ground movements and excavation. The definition of the product phase is considered as very versatile, particularly the possibility of using different measuring units and the unit conversion calculations in place, although complex and time consuming. Limitations of the product database- linked to the lack of EPDs for building products- forces the designer to apply simplifications.

Despite the room for improvement, 66% of the users found the tool very useful (scoring 4 or 5 out of 5) and 16%gave it a fail under usefulness score.

Specific improvement suggestions to the tool included expanding the product and construction systems database, linking the tool to an energy simulation tool to obtain the inputs for the use phase directly without having to calculate them separately. Links to costing tools were also seen as an advantage. Expanding the systems boundaries to include the end of life phase is also considered necessary.

Discussion and conclusions

The EnerbuiLCA project provides a simplified and user friendly LCA tool and associated databases. The tool allows the incorporation of new elements to allow the assessment of real case studies in case this information was not available from the database. Despite its limitations, its application brings the LCA methodology closer to a broader public who is not necessarily familiar with it. This way, users have all the necessary information in their hands to be able to consider energy and environmental impacts when selecting materials, suppliers and more eco-efficient production processes.

Although the impact assessment in the EnerBuiLCA tool is based primarily on indicators of energy consumption and GHG emissions in line with the current environmental concerns, it would allow other environmental indicators (energy, water and financial), always from a life cycle perspective.

The URBILCA project- also presented in this congress- capitalizes the results of the EnerBuiLCA project, includes the end of life phase, further extends its spatial boundary to the urban scale and includes an indicator for water consumption. This will jointly contribute to an improvement in energy management in buildings and urban areas.

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Energy Rating Software with a Life Cycle Approach

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Abstract: *This paper describes the on-going process for the development of a new software tool, SOFIAS (Software de Funciones Integradas para una Arquitectura Sostenible), partially funded by the Spanish Ministry of Economy and Competitivenes. This tool is developed to assist building professionals on the sustainable design of buildings, with particular emphasis on reducing the environmental impact through the building life cycle assessment (LCA). Throughout this paper are explained the general objetives, the innovative points, the working methodology and the different type of results that can be generated by SOFIAS.*

As summarized in the conclusion section of the paper, the main objective of SOFIAS is to develop an innovative rating system based on the assessment of the sustainability of new and rehabilitated buildings with life cycle perspective.

Keywords: LCA Software, Environmental Building Declaration, Life Cycle Assessment, Life Cycle Cost, LCA Database, Rating system, certification

Introduction

The environmental assessment of buildings with a life cycle approach still seems new for most professionals involved in the construction sector. However, due to new regulations and environmental quality requirements of the European market, LCA is becoming more present in their activities. Evidence of this is the intense normative work on the assessment of the sustainability of buildings carried out by the European Committee for Standardization and specifically, the technical committee TC/350 [1]. The European market has different LCA tools for modelling and impact calculation (Simapro [2], Gabi [3], Umberto [4], EcoQuantum [5], etc). However, these tools require expert knowledge in building definition and assessment with LCA perspective and do not have specific national environmental databases for construction products.

Along with the problem of the complexity of this type of tools, one of the main reasons for the development of this software is focused on providing a solution to the fact that the current Spanish energy certification tool, Calener [6], only quantifies the environmental impacts associated with the use stage of the building. When full life cycle impacts of a building need to be assessed, a second and completely independent study is required which increases efforts and costs.

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This paper describes the development of an experimental prototype tool compatible with the standard CEN 350 to respond to different needs of professionals regarding full life cycle assessment of buildings, such as

1. **Need for evaluation of environmental aspects** in the design, construction and refurbishment of buildings considering the full life cycle. It is important that professionals can have this new environmental vision from the beginning of the design process. Need of **reference values to allow** definition and evaluation of the environmental and economic performance of the building during the different stages of life cycle.

2. Need of **free generic environmental data** of materials and processes related to the Spanish construction sector. Currently, the professionals have the possibility to get this kind of information from Environmental Product Declarations (EPD) or from Data Base like Ecoinvent. However, difficulty to access and interpret this information means that in many cases the user dismisses the option to continue their work.

3. Need to perform environmental calculation of all building stages and obtain the Environmental Building Declaration (EBD) with **very little work and** without duplicating work from energy rating.

To respond to these needs, SOFIAS tool has been developed making possible to analyze, quantify and optimize environmentally and economically each building throughout their life cycle, and to obtain an EBD and a rating result, which will be a further incentive for the design and development of innovative and differentiated buildings.

SOFIAS Innovation in relation to other tools

The proposed tool SOFIAShas a great potential to be used on a large scale by construction agents, mainly designers, such as architects or engineers. In addition, given its clear focus on providing information on compliance with environmental quality standards, SOFIAS could be used in green public/private procurement, in the development of new regulations and in voluntary assessment (Environmental Building Declaration and Rating).

<u>The tool can link to national energy rating tools and is presentrly directly related to the Spanish energy labelling tool Calener</u>. Through the communication between the "xml" file generated by Calener and the software of SOFIAS, the user automatically could import most of the building information simulated by Calener, becoming SOFIAS as a new extension of the current official tool.

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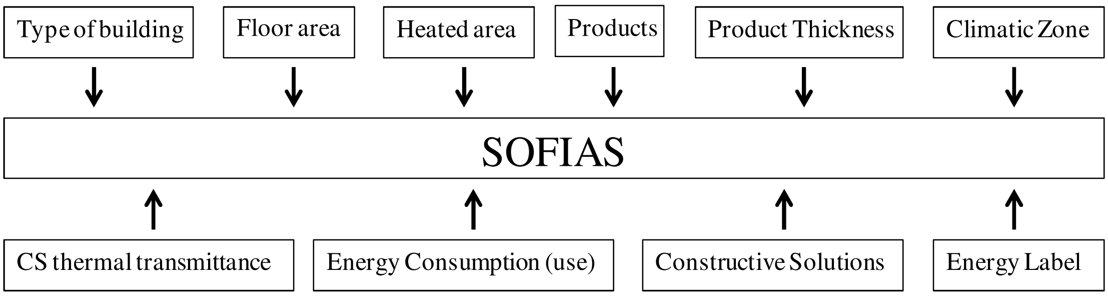

Imagen 1 Parameters imported from Calener to SOFIAS

<u>EPD and Generic Environmental Data Base</u>: One of the main efforts during the tool development has focused on generating an open and generic environmental database of building products and constructive solutions for Spain. This database is based on values from EPDs complying with ISO 14025 [7] and 15804 [8] structure, and on generic values obtained and validated by the SOFIAS consortium. Until now, users had to search for environmental information through various private and public sources. However, through SOFIAS, the user can get generic values of environmental impact for products, constructive solutions and some energy systems from the integrated database for Spain.

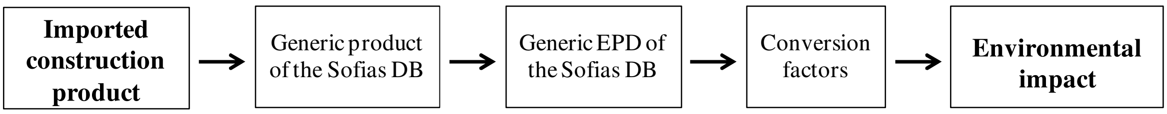

Imagen 2 Outline of the methodology to calculate automatically the environmental impact of the product imported from Calener (more information in the Paper Number 612)

The algorithm of SOFIAS allows relating the materials imported from Calener with the generic environmental impact of that material. For this, it has developed a new system of codification for the construction sector in Spain, linking all inputs and equations within SOFIAS. In case that the final user has precise data of a manufacturer EPD, SOFIAS allows to link manually this EPD to the imported construction product.

<u>New algorithm</u>: SOFIAS has developed a new algorithm to implement the calculation logic in the software and to carry out the validation of the software by AENOR (Spanish Association for Standardisation and Certification)

<u>Working at different Levels</u>: SOFIAS is not a static tool. It has been scheduled to be part of the dynamic development of the architectural project, defining 3 different working levels, from a very general Design level until an After Project Level with highly detailed information. This definition of levels provides the possibility of making decisions at each stage of the project. During the first level, “Design Level”, SOFIAS provides large part of the building definition information, obtaining a global environmental impact of the building. It is during this stage when still the building will not be fully defined and the user may detect critical points and propose general changes. During the second level, “Project Level”, the definition of the building is more accurate, using fewer default values and the implementation

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of the algorithm is more complete. Finally, if SOFIAS users want to obtain Environmental Building Declaration (EBD), they should use "After-Project Level".

Environmental rating tool with life cycle perspective in Spain: SOFIAS results on an environmental rating of the analyzed building, enlarging the scope from the actual energy rating to include detailed environmental impacts over the full life cycle of the building. This rating allows professionals to assess the environmental impact of their building through the comparison against a reference building.

SOFIAS Certification: following the Certification Regulation defined by AENOR, the data quality requirements and the correct application of the algorithm of calculation are chequed amongst other factors, offering the end user the possibility to obtain the environmental Certification SOFIAS, if minimum data quality requirements are met.

Economic input. In conjunction with the environmental analysis, SOFIAS enables the user to perform an economic analysis of the different stages of the building: 1-construction of the building (materials/systems and construction stage), 2-Operational Stage, where the user may evaluate various energy scenarios defining the energy price and proposing different price increases and 3-Management of end of life.

SOFIAS methodology and its aplication

The general structure of the SOFIAS tool is mainly based on 4 sections:

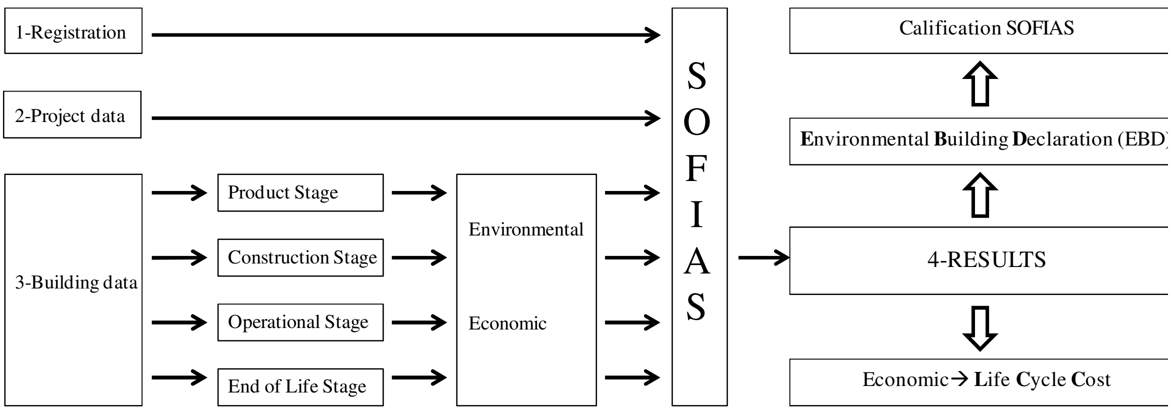

Imagen 3 General outline of the SOFIAS Structure

Registration: data regarding the final user (without influence in the calculations).

Project: general characteristics of the project. Between these data are defined the Type of Project (new construction / renovation) and Working Level (design / project – after Project), whose election will influence directly on how to insert the data of the building, in the calculation and in the environmental requirements defined by SOFIAS. In an initial evaluation of the building is recommended to select the Design Level, being able work in a very simplified form. However, when the definition of the project is sufficiently advanced, it will require the following working levels.

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Building: it is the most complete section, where according to the data defined in the "Project", the user will define with different degree the building characteristics along its 4 main stages.

During the first stage, Product Stage, SOFIAS quantifies the environmental impact (Initial Embodied Energy) of the constructive solutions (facade, roof, internal partitions, walls in contact with the ground and windows), structural elements (foundations and pillars) and installations (renewable and non renewable). Importing the "xml" file generated by Calener and with the reference values defined by SOFIAS, the user automatically may obtain the required values to calculate the environmental impact of constructive solutions.

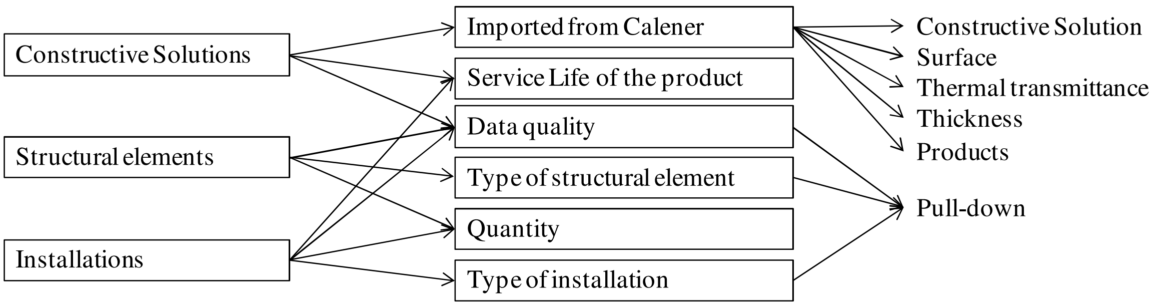

Imagen 4 Outline of the Product Stage methodology

During the second stage, Construction Stage, SOFIAS quantifies the environmental and economic impact of the construction process, transport of the materials and earthworks.For the Design and Project working Levels, based on national statistics (Spain) and defined by the consortium partners, SOFIAS provides automatically information for each constructed square meter: energy consumption (MJ/m2), water consumption (m3/m2) and waste generation (kg/m2). For the After Project Level, the user should define all these data.

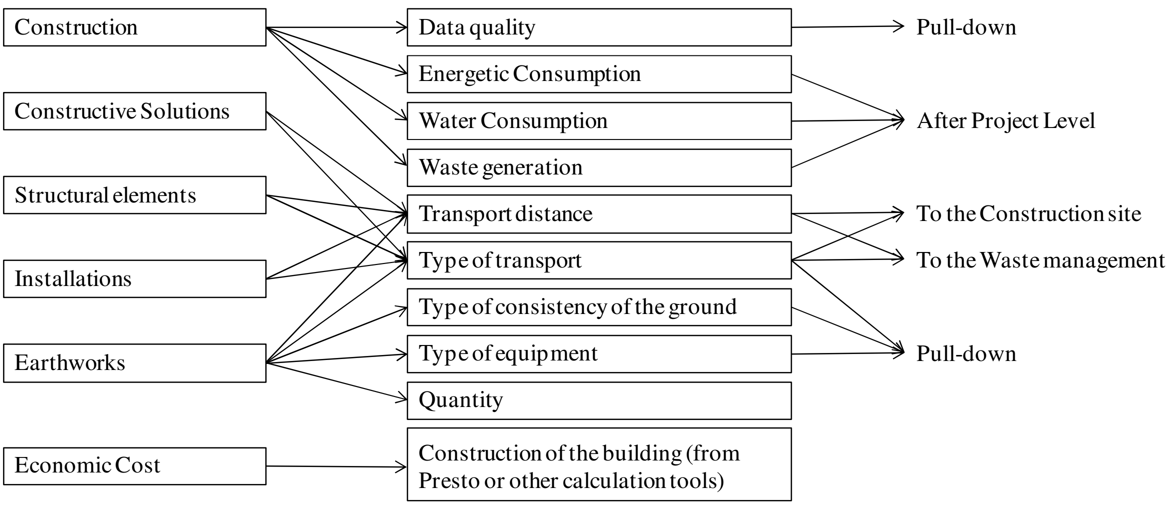

Imagen 5 Outline of the Construction Stage methodology

During the third stage, Use Stage, SOFIAS quantifies 2 types of impacts. On the one hand there is the impact related to operational energy consumption of the building, which can be calculated by other simulation tools (Design and Project Level) or introduce the values of the

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actual receipt (After Project Level). Through this last option, SOFIAS facilitates optimizing the actual environmental performance of the building during its use phase. On the other hand there is the impact related to the recurrent embodied energy (REE), which represents the sum of energy inputs associated with the energy required to manufacture and replace materials across the useful life of the building. In SOFIAS materials are replaced at the end of their service life.

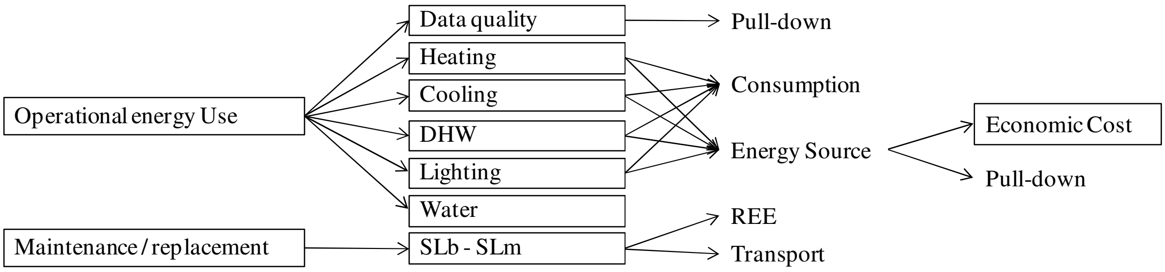

Imagen 6 Outline of the Use Stage methodology

Finally, during the End of Life Stage, are defined the different waste management systems related to end of life of each element of the building. Large percentage of the information is focused on the data base values, where SOFIAS contains information about different end of life scenarios. However, during the After Project Level, the user will have to introduce the data for their case study.

<u>Results</u> After entering data in each section, Sofias automatically performs calculations, showing the enviromental/economic impact and the new energy rating of the building. For the cases analyzed by After-project Level, SOFIAS shows the data quality and the possibility of opting to the Certification Sofias. It should be clarified that the energetic mix applied is the Spanish energetic mix with lifecycle perspective.

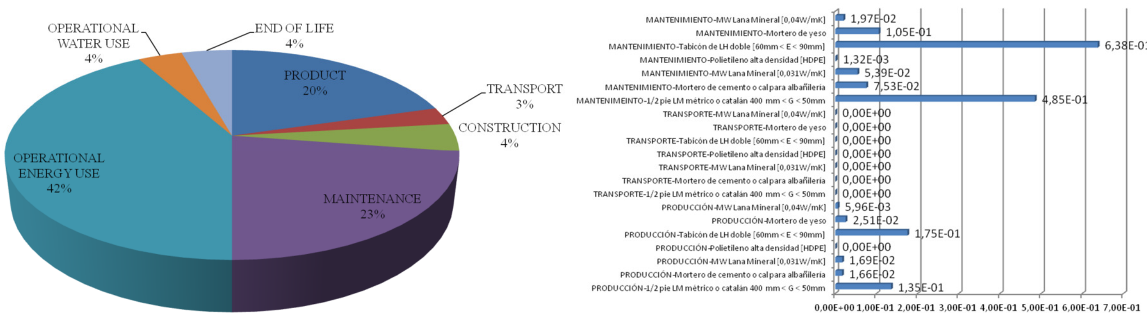

Imagen 7 Different breakdown of the SOFIAS results (kg CO2eq/m2heated year): in stages throughout their life cycle (1) and for each material (2)

SOFIAS offers the possibility to display the results in different formats, adapting to the needs of each user or project:

- **Breakdown:** visualise the impacts throughout the life cycle stages (general), for each group or for each product (detailed), enabling to optimize each decision.

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- **Functional Unit**: visualise the total environmental and economic impact of the building or per $1m^2$ heated/year.

- **Indicators**: SOFIAS performs the calculation for indicators marked by the 15978 regulations. However, in order to facilitate the reading of the results, the user can select the indicators which want to display in the interface.

	GWP impact (kgCO2/m2*heated*annum)
Case Study Building	28.6
Reference Building	32.4
SOFIAS RATING	★ ★ ★

Imagen 8 SOFIAS final result (GWP indicator) and Rating

Discussion and Conclusion

The main objective of SOFIAS is to develop an innovative software tool for evaluation and rating of the sustainability of new and rehabilitated buildings. After a study of professional needs, the software integrates new features such as linking with national energy rating tools and with generic LCA databases. The software includes an environmental rating methodology and offers the possibility of certifycing the environmental rating. The current version will be further improved with input from users, new standards, new softwares and Databases. Furthermore, results from real projects will be used to create a benchmarking database in order to evaluate new materials, technologies, standards, rating systems and define Best Available Technologies with Life cycle perspective.

Acknowledgements

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An Early-Stage Life Cycle Model for Low-Energy Buildings

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Abstract: *The aim of this study is to demonstrate the application of a model previously developed by the authors for low-energy building design, to show how the availability of comparable energy performance information at the building design stage can be used to better optimise a building's energy performance. The life cycle energy demand of a case study building was quantified using a comprehensive embodied energy assessment technique and TRNSYS thermal energy simulation software. The building was then modelled with variations to its external assemblies in an attempt to optimise its life cycle energy performance. The alternative assemblies chosen were those shown through the authors' early-stage life cycle energy model to result in the lowest life cycle energy demand for each building element. The study showed that significant life cycle energy savings, up to 45%, are possible through the modelling of individual building elements for the case study building.*

Keywords: life cycle assessment; embodied energy; thermal simulation; climate; low-energy building design; building assemblies

Introduction

A holistic approach to low-energy building design is essential to ensure that any efficiency improvement strategies provide a net energy benefit over the life of the building. In order to achieve the optimal environmental performance of a building, environmental assessment tools must be developed which can be easily implemented during the early-stage design phase to facilitate quick assessment of potential assembly alternatives. The choice of building materials has a significant effect on the total energy demand associated with constructing and operating a building. Although it is suggested that buildings are responsible for approximately 40% of global energy consumption, relatively little has been done to address the growing life cycle energy demands associated with buildings.

Findings from research and reliable data about the environmental performance of building materials and components are often not readily available to building designers. Furthermore, despite the abundance of building energy research, these rarely incorporate the energy demand across the full life cycle. Previous studies that have considered the life cycle energy (LCE) demand of buildings, typically use incomplete or unreliable data, or are based on flawed methods of assessment. Previous work by the authors established a model for informing low-energy building design based on a comparison of the life cycle energy demand associated with a broad range of building assemblies [1]. Assemblies are ranked based on their combined initial and recurrent embodied energy and operational energy demand. Further studies applied this model to a single detached residential building in order to demonstrate the application of the model for optimising a building's life cycle energy performance [2]. The aim of this study is to apply this model to a multi-unit residential building in a different climate in order to demonstrate its ability to optimise a building's energy performance during early-stage building design.

Background

Limited consistent and comprehensive information is available to assist in informing decisions for reducing the life cycle energy of buildings [1]. Previous life cycle energy studies of individual houses [inter alia 3,4,5,6,7] rarely demonstrate the use of a particular approach or method which could be employed in the early design stages to optimise energy performance. Most previous studies that have proposed methods for optimising the life cycle energy performance of individual buildings have typically focused on either the embodied energy (EE) of buildings [for example, 8,9,10,11] or modelled their heating and cooling requirements [for example, 12,13,14]. The research which has come closest to providing data that can be employed by design professionals in the selection of building materials or assemblies to optimise building energy performance include that by Yao and Steemers [15] and Utama and Gheewala [16] as well as that conducted by Lawson [8] and BRE [10]. However, again, the focus from an energy perspective is limited to initial EE, excluding energy requirements associated with the replacement, operation and maintenance of materials [1]. The ATHENA® EcoCalculator for Assemblies [17] provides environmental performance data for common building assemblies and includes both initial and recurring EE, but excludes operational energy (OE). Studies that have incorporated both EE and OE parameters include those of Chen *et al.* [18] and Pierquet and Bowyer [19]; however, many gaps and the use of unreliable, potentially erroneous data are apparent [1].

Early-stage life cycle energy model

The model previously developed by the authors [1,2] used TRNSYS software and EE modelling to determine the LCE of a range of residential construction assemblies. This was tested using a case study house, demonstrating how the availability of a model which could be implemented at the early design stage to quickly compare and select building elements, could maximise the LCE performance of a building design. The EE component of the model was based on the input-output-based hybrid approach (IOBHA) developed by Treloar [20]. This IOBHA model addresses many of the problems associated with pure process-based analysis methods (which can lead to EE values that are up to 87% incomplete [21], as process analysis suffers from a systematic incompleteness [1]) by starting with a disaggregated input-output model to which available process data is integrated [1]. The advantage of an input-output model is that it enables a systemically complete analysis of the energy requirements associated with any product system; however, as it is based on national average data, its use does limit the applicability and reliability of results for any specific product. A more in-depth explanation of the early-stage life cycle energy model and the associated method are provided in [1]. The current study extends on the previous research by considering the extent to which the use of the LCE model at the early design stage can reduce the LCE demand of a multi-unit residential building.

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Method

This section describes the approach used to calculate the life cycle energy (LCE) of a multi-unit residential building in order to determine the degree of energy savings possible with early consideration of a building's LCE performance. The study involved quantifying the life cycle energy demand of the as-built case study building, including its initial and recurrent embodied energy and heating and cooling energy demand. The building was then re-modelled with variations to its external assemblies in an attempt to optimise its life cycle energy performance. The alternative assemblies chosen were identified by the LCE model as those most likely to perform the best from a LCE perspective for the particular climate.

Case study building

A three-storey multi-unit residential building, of typical residential construction, was selected for analysis. This example was chosen as it was considered to have numerous opportunities for improving its energy performance. Furthermore, being located in the temperate climate of Bendigo, Australia (Lat. 37°45′S, Long. 144°16′E) it allowed for testing the applicability of the model in a different climate zone than in previous work. The building has a floor area of approximately 790 m^2.

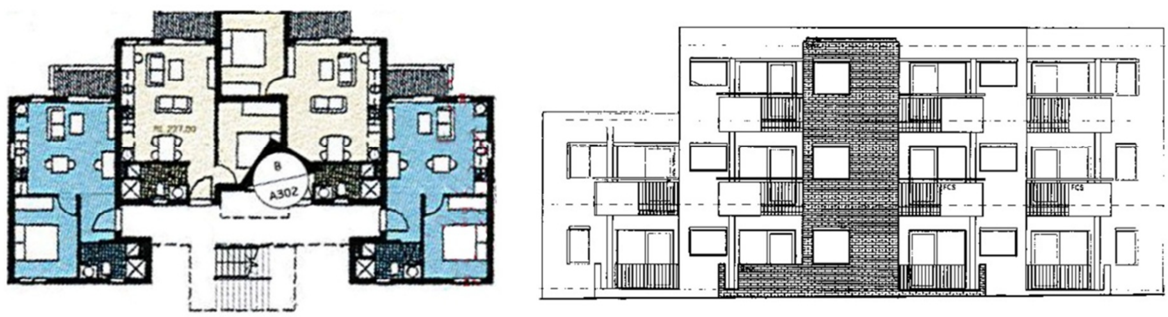

Figure 1 Floor plan and north elevation of the case study building

The external assemblies and materials used include concrete slab-on-ground construction for the floor; brick veneer timber-framed walls; and timber-framed steel-clad roofing. Details of the construction materials of the as-built building are shown in Table 1.

Table 1 Description of assemblies for the as-built case study building

Element	*Assembly*	*Description*
Roof	Timber frame, steel sheet	Corrugated steel sheet, 50x35 mm hardwood battens, 100x50 mm softwood trusses, 90x35 mm softwood joists, RFL, R3.0 fibreglass insulation, 10 mm plasterboard, water-based paint
External walls	Brick veneer, timber frame	Standard clay bricks, 90x45 mm softwood framing, RFL, R2.0 fibreglass insulation, 10 mm plasterboard, water-based paint
Floor	Concrete slab on ground	Water-proof membrane, expanded polystyrene waffle-pods, steel reinforcement, 110 mm 25MPa concrete, ceramic tiles

Embodied energy analysis

An input-output-based hybrid approach was used to calculate the initial and recurrent EE of the as-built building over an estimated life of 50 years. Available process data, obtained from the latest available SimaPro Australian database [22], was integrated with national average input-output data, taken from the Australian National Accounts [23] and combined with energy intensity factors by fuel type, as per Treloar [20]. This data is used to produce hybrid material energy coefficients for a range of common building materials. The total EE for the as-built building was determined by multiplying the quantities of the materials used in the building by their respective energy coefficients and summing the results.

Calculating the recurrent EE required assigning replacement rates to materials used in the initial construction, based on the likely exposure to deteriorating effects for each material. The estimated useful life or replacement period for the materials used in the as-built building can be found in [1]. It should be noted that factors such as changes in manufacturing procedures, associated with the replaced materials over the life of the building will influence EE values. However, for the purpose of this study, the recurrent embodied energy (REE) figures remained constant. Equation (1) was used to calculate the life cycle embodied energy of the building.

$$LCEE = \sum_{m=1}^{M} \left(\left\lceil \frac{UL_b}{UL_m} \right\rceil \times EE_m \right) \qquad (1)$$

Where *LCEE* is the life cycle EE of the building; UL_b is the useful life (years) of the building; EE_m is the total EE (GJ) of material, *m,* within the building; UL_m is the useful life (years) or replacement period of material, *m*.

Heating and cooling energy demand

TRNSYS thermal simulation software was used to measure the relative heating and cooling energy requirements for both the as-built and alternative assemblies, modelled on the base case building. Australia Representative Meteorological Year Climate Files (RMY) [24] were used to represent average Bendigo climatic data and a simulation was run in TRNSYS to determine the predicted heating and cooling loads for the building for one year. This was then used to predict the energy demand that would be required over the assumed 50 year life of the building. Assessment parameters were as follows: heating and cooling were turned on between 8am and 9pm when temperatures fell below 18ºC or rose above 24ºC, respectively; initial zone temperature was 20°C; initial humidity was 50%; ventilation, heat gains from people, computers and artificial lighting were excluded. Hourly solar radiation, dry bulb temperature, relative humidity and Bendigo climatic data were used to determine the heat loss/gain through the external envelope of the as-built building and therefore the energy required annually to maintain the internal temperature between 18ºC and 24ºC.

The output obtained was converted to primary energy terms to account for the impacts associated with its production and to enable a comparison with the EE values. A factor of 1.4 was used for natural gas heating and 3.4 for electric cooling. Energy required for hot water, lighting, appliances and cooking were not included as the characteristics of the external envelope of the building do not significantly affect this energy demand. Also, the energy associated with the end-of-life demolition and disposal of materials was not included, as Crowther [25] has shown that the energy associated with this stage of a building's life typically represents less than 1% of the building's life cycle energy requirement.

Optimising the life cycle energy performance of the as-built building
The early-stage life cycle energy model indicated, through a process of ranking assemblies in order of their life cycle energy performance, that the LCE of the as-built building could be improved by replacing the brick veneer walls with rammed earth and the steel sheet roofing with concrete tiles [1]. However, as rammed earth was not considered suitable for this building type, the brick veneer was substituted with Hebel panel for the walls, as it was considered, in consultation with the architects, a viable alternative for this particular building. Likewise, concrete tiles were not considered a practical option for this particular building and hence the steel sheet roofing remained for the optimised scenario. The LCE model showed that a concrete slab on ground was the preferred option from a life cycle energy perspective and so this remained for the optimised scenario.

The as-built building was altered, as per Table 2, based on the ranking of common residential building assemblies presented in the previous study by the authors [2]. The LCE of the optimised building was then re-calculated to determine the potential energy savings possible due to the alternative assemblies.

Table 2 Description of as-built and optimised assemblies for the case study building

Element	*As-built assemblies*	*Optimised assemblies*
Roof	Timber-framed, steel deck	Timber-framed, steel deck
External walls	Timber-framed, brick veneer	Hebel panel
	R2.5 Glass wool insulation	R3.0 Glass wool insulation
Floor	Concrete slab on ground	Concrete slab on ground

Results and Discussion

This section presents the results of the LCE assessment of the as-built building, compared with the optimised building, in order to demonstrate the impact that a model for optimising building life cycle energy performance could have if utilised during the early-stage building design phase. Figure 2 shows the breakdown of the life cycle energy for the as-built and optimised buildings for a period of 50 years, in primary energy terms. The total estimated energy requirement for initial construction, heating and cooling and maintenance and replacement of materials in the as-built building is around 10,479 GJ. The initial EE represents 39% of the total life cycle energy demand, only slightly below the total heating and cooling energy demand. Recurrent EE represents approximately 53% of initial EE and 21% of life cycle energy. The total estimated energy requirement for initial construction, heating and cooling and maintenance and replacement of materials for the optimised building is around 4,668 GJ, 45% below that of the as-built building. This reduction in overall energy demand can be attributed to the substitution of assemblies in the *as-built* scenario with those that provided a better balance between EE and heating and cooling energy demands. The initial

EE represents 47% of the total life cycle energy demand, only slightly below the total heating and cooling energy demand. Recurrent EE represents approximately 24% of life cycle energy.

Although the floor and roof building assemblies were not altered for the modelling of the optimised scenario, due to building requirements and regulations associated with this building type (such as fire ratings, etc.), the optimised scenario was still able to considerably outperform the as-built building.

While the life cycle EE was able to be lowered in the optimised building, it is interesting to note that it actually accounts for a larger portion of the overall LCE of the building; 47% in the optimised scenario, compared with 39% in the as-built case. This highlights the need for more focus on EE as buildings become increasingly more operationally efficient, often at the cost of a higher EE associated with the use of new technologies and more advanced and energy-intensive building materials.

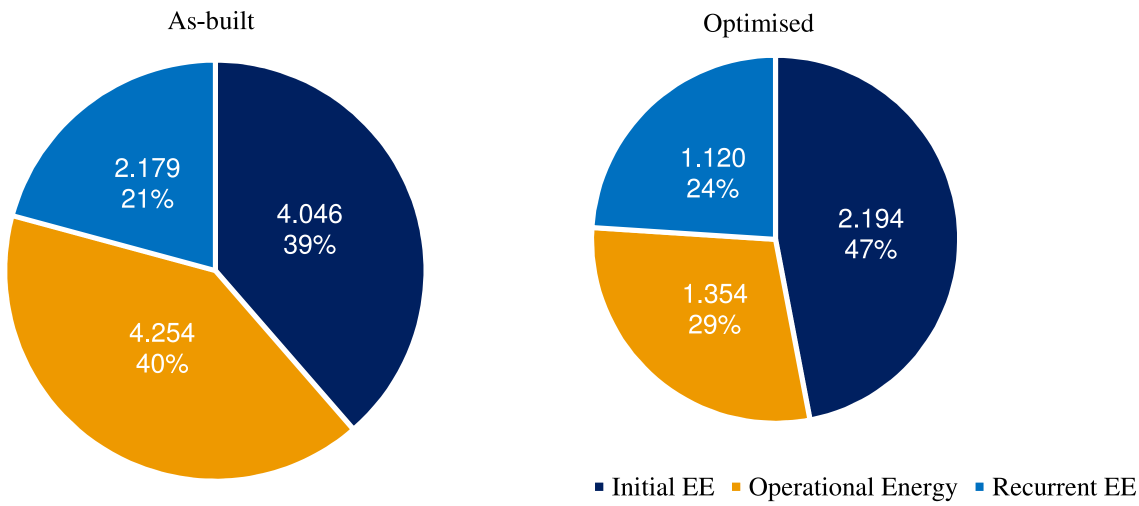

Figure 2 LCE comparison of as-built and optimised case study building

Moreover, with the likelihood of an increasing proportion of renewables in the energy mix, the focus should immediately shift towards EE, particularly due to the long lag between consumption and its effect on the environment, especially in regards to climate change. Energy used today as embodied energy is going to have a much greater effect on the environment than operational energy used in the future, with a higher proportion of this also likely to come from renewables.

Conclusion

While the findings of this study relate to a very specific case, they demonstrate the application of a model for optimising building life cycle energy performance that may be useful during early-stage building design. This study has demonstrated through the case of an *as-built* building how the availability of comparable energy performance information for individual construction assemblies could have been used to better inform the design of the building to optimise its energy performance. Furthermore, it showed that the selection of individual building assemblies to minimise life cycle energy can result in significant energy savings - up to 45% for the building analysed.

With the use of a comprehensive embodied energy assessment approach, this study has further reinforced the findings of previous research that the EE requirement across the life of a building may be greater than the energy required for heating and cooling. This demonstrates that in any attempt to improve building energy performance, quantifying and addressing EE demand in a life cycle context is of vital importance. The focus should no longer be solely on reducing the amount of energy which is consumed in heating and cooling buildings.

This study has also highlighted the fact that there are multiple factors and priorities at play during building design. Energy is one of these important factors, yet other priorities may mean that the optimal solution from a life cycle energy perspective may not be possible due to competing priorities, such as local building regulations, costs, labour availability etc..

Ultimately, the findings from this study will be used to further develop a design tool for use by architects and building designers. Design and construction professionals will be able to increase the life cycle energy performance of buildings by selecting assemblies that result in the lowest life cycle energy demand, based on their comparative ranking. This information will be available prior to having a design solution resolved, rather than after key decisions have been made, as currently occurs in many environmental assessment tools.

Acknowledgements
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Added value of the European Core EPD

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Abstract: *European Core EPD (Environmental Product Declaration) may reduce the effort for building product manufacturers while the industry will be enabled to communicate relevant environmental data in a harmonized format. The ECO Platform[1], the organization of EPD providers, is working on the procedures to guarantee a quality and international acceptance of EPDs. Several EPD Program Operators, promoting the idea of harmonization, in a transparent and democratic manner founded the ECO Platform as AISBL organization on June 4, 2013. ECO Platform mission is to replace multiple EPD formats with one compatible format for core content to be used throughout Europe and European policies.*

ECO, EPD, LCA, BR7, PEF

Environmental Product Performance - Overview

Europe is a part of global market area and any European Standards for declaring environmental information on construction products should be in line with the relevant framework. Especially from the regulatory point of view the environmental indicators described in EN 15804:2012[2] should be regarded as a basket of indicators that have an agreed scientific basis for European standardization. EN15804 relates to the environmental assessment of construction products:

- defines the parameters to be declared and the way in which they are collated and reported
- describes which stages of a product's life cycle are considered in the EPD
- defines rules for the development of scenarios, includes the rules for calculating LCIA underlying the EPD, including the specification of the data quality to be applied
- includes the rules for reporting predetermined, environmental and health information, that is not covered by LCA for a product, construction process where necessary
- defines the conditions under which construction products can be compared

This standard essentially provides a basis for creating a national PCR (Product Category Rules) document and defines the key methodological decisions that have to be made. One of the purposes of defining these choices is to resolve the differences between European national EPD programs and, by doing so, facilitate the mutual recognition of EPD both across borders and within the various building assessment schemes that exist in Europe. There is a clear advantage for construction product manufacturers in this approach as they will need to produce fewer EPD to cover International trade within the European Union. CEN TC 350 responsible for this standard development expect that feedback received during the first years of the standard will form the basis for subsequent revisions. As expected, practical experience of implementing EN15804 has shown that there are many areas of the standard that are not yet fully resolved. The implication of this is that EPD produced to different EN15804 compliant PCR documents may not be directly comparable: EN15804 requires EPD to contain a statement to this effect. Differences may be introduced by factors such as the choice and availability of the background data that EN15804 requires, the detail of modelling assumptions and the optional exclusion of certain lifecycle stages from EPD. This potential lack of comparability creates an obstacle to the use of EPD from different schemes within LCA design tools and building assessment schemes [3]. In response, large group of construction sector stake-holders actively collaborating with a group of European EPD programs providers to agree a process for developing and managing a core set of rules for implementing EN15804. This harmonization work ensures that the views of all parties are considered, and that the agreed rules are developed objectively and independently. The formal title of this group is the 'ECO Platform'.

European ECO PLATFORM

25 organisations from 17 European countries agreed on establishing the European EPD Platform[1]. The European construction products industry is going ahead with the standardization of EPD as agreed a meeting in Brussels on 23 September 2011. 11 EPD program operators:

- Environdec System - AB Svenska Miljöstyrningsrådet (Sweden),
- EPD Norge - The Norwegian EPD Foundation (Norway),
- IBU - Institut Bauen und Umwelt e.V. (Germany),
- BRE Global - Building Research Establishment Limited (UK),
- Association HQE tio (France),
- Stichting MRPI - Milieurelevante Productinformatie (Netherlands),
- ITB - Instytut Techniki Budowlanej (Poland),
- DAPc - CATEEB - Colegi d'Aparellafdors, Tècnics i Enginyers d'Edificació (Spain),
- Global EPD - AENOR - Asociacion Espanola de Normalización (Spain),
- DAP Habitat - CentroHabitat (Portugal),
- ZAG EPD - Zavod za gradbeništvo Slovenije (Slovenia),

signed a "Memorandum of Understanding" to establish an umbrella organization beyond national systems. On September 24, 2013 ECO celebrated the official launch of the ECO Platform together with over 80 participants in Brussels including DG ENV representatives. ECO Platform aims at initiating the development of a uniform and European core EPD . The basis for the ECO Platform is the work of CEN TC 350 on product sustainability. The objective of ECO is to support the provision of unbiased, credible, consistent and scientifically sound information in a form of type III Environmental Product Declaration for construction products (Image 1). This objective is achieved by following steps and actions:

- development of a common EPD core system for construction products based on ISO 14025 (ECO platform is not intended to be a European program operator)
- development of consistent implementation of EPD according to EN 15804
- elaboration of a common European format (interpretation) based standards
- description of a common quality management and verification procedure leading to mutual recognition across national borders

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ECO is the organization based on EPD program operators (one vote per country in the Board). Platform includes supporting members such as Associations, GBCs, EU Commission representatives, CEN observers. ECO is aiming for being widely visible and recognized as the benchmark for EPD Program Operators in Europe.

Image 1. The added value of the ECO Platform [1]

There are voices form European Commission that ECO would harmonize EPD market as necessary thing for new requirements of the regulation CPR (EU) No 305/2011 of the European Parliament and of the Council, as of March 9th 2011, laying down harmonised conditions for the marketing of construction products. CPR defines relevant product-specific information in the Basic Requirements (BR). The BR 3 (hygiene, health and the environment), BR6 (energy performance) and BR 7 (sustainable use of natural resources) are now taking up the life-cycle approach. However, no legally binding requirements are connected and CPR does not specify how to prove the compliance with the BR, except the indication of EPDs as a possible format: “For the assessment of the sustainable use of resources and of the impact of construction works on the environment Environmental Product Declarations should be used when available.” (CPR, recital 56). At this stage, EPDs are a possible, but voluntary, format for proving the compliance with the new BR requirements.

It allows the industry to provide product data for the relevant indicators without the obligation to keep any thresholds. Btw uncoordinated development of EPD programs in Europe would inevitably lead to a confusing collection of inconsistent EPD systems, which are not harmonized and therefore not to be used equally. Europe-wide active manufacturers would be forced to issue many EPDs or even other labels with similar content in order to be present on all markets. This confusion would put barriers to trade, and therefore probably result in the development of either a rigid regulation by the EC or large certification firms would start to fill this gap. The industry is demanding a harmonized EPD methodology recognized on a broad international level, in order to avoid barriers to trade and to reduce the effort for providing product data. Using a common EPD methodology for European market can be the adequate solution. ECO Platform aims to facilitate and coordinate the agreement for a common EPD scheme among “sovereign” EPD to: ensure an optimal use of the standards in existing structures, to provide a level playing field in the marketplace for all participating manufacturers, to develop a common language for product and building performance assessment. All harmonization work in ECO is done by Working Groups. WGs have the task to define form and content of the ECO Core EPD as well as the quality management.

Actual tasks of WG I “Technical Issues”

- Common interpretation of existing standards
- Identyfication of issues in EN 15804 that will profit from a common interpretation
- Definition of scenarios for a full life cycle EPD
- Manual to EN 15804, implementation of the guidance document
- Data quality and data sources, solutions for the use of different background databases
- Common solutions for program operators
- Comments for CEN TC 350 as a liaison partner, for this a liaison status is needed
- Supporting further development of EPD in the construction sector

Actual tasks of WG II “Quality Management and Verification”

- Qualification /accreditation of verifiers, including quality and expertise check
- Manual for verification, including procedures, check-list format, report format
- Adaptation of existing EPDs to new rules

Tasks of WG III “Internal & External Affairs”

- Provide common messages for external communication
- Report the external activities related to the ECO Platform to the Members
- Define hierarchy of messages and clear communication streams
- Monitor activities of the concerned players (CEN, EOTA, EC, Member States…)

Other important work for EPD providers to step forward is to: collect all technical issues from the EPD operators, discuss how the issue is dealt with at different programs, with the goal of finding a common solution, use the format of the future guidance document for EN 15804. The actual problem is a double work with CEN TC 350 WG3 so the liaison status is needed. Other issues to be solved are: how to deal with so called “EPDs” without a program operator, develop a better guidance around module D, aslo the term "construction product" needs a more common understanding according to CPR, what to do with long term emissions, avoided impacts, system boundaries for packaging, how to deal with averages.

Correlation with ISO TC59 SC17 WGI, revision of ISO 21930. There was no decision taken in relation to cooperation with EOTA. Although there are clear synergies and some worries occurred from ECO Platform side. It was recommended that EOTA fosters collaboration with ECO Platform in order to support the mission of ECO Platform and provide experts’ advise.

The European Commission- PEF or EPD?

The publication of the European Commission (EC) Communication on “Building the Single Market for Green Products” (COM/2013/0196) on 9 April 2013, and welcomes its aim to “contribute to improving the availability of clear, reliable and comparable information on the environmental performance of products and organisations to all relevant stakeholders”. The key part of this Communication is the Product Environmental Footprint (PEF) guide which uses a LCA approach to measure the environmental performance of a product or organisation throughout its life cycle. However, there are doubts from construction sector stake holders about PEF methodology for assessment of construction products. Main problem is that CEN TC 350 already developed the standards. The proposed PEF allows to calculate the environmental footprint of a product. In the construction context, the product is the building, in the other words, construction products are intermediate products, so it makes no sense to assess them outside the building context. Most of ECO members believe that EN 15804 methodology should be considered as the reference document for the PEF assessment. EN 15804 method and EPDs for construction product are recognized by the market. Since PEF approach recommends the development of sector-specific rules (PEFCRs), the industry (strongly represented in CEN Product TC) is rather willing to work with the Commission with using the CEN TC 350 methodology as the PEFCR for buildings. Because of the specificities of the assessment of a building, PEF methodology would require changes if applied to industry. As indicated above, CEN TC 350 environmental assessment methodology and PEF can be considered as equivalent, provided that PEF does not look at construction products individually but at the building as a whole. Moreover the approach of CEN TC 350 is different from PEF when it goes beyond the end of life of the system. The long life and complexity of construction works mean that the end of life stage cannot be considered in the same way as for short-lived consumer products. It is essential that the indicators required for

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construction products and the methodologies used to calculate them should be the same all across Europe. The use of the PEF could be acceptable for construction products, if PEFCRs for construction sector is totally based on CEN TC 350 standards and all contradictory elements of the PEF were ignored.

The European Commission- BWR7

The European Commission, i.e. DG ENTR started process on the implementation of BWR 7. With reference to the recital 56, DG ENTR proposes that BWR7 should be translated into product performance characteristics on the product level based on EPDs. The product performance characteristics should be incorporated into harmonized product standards via mandates to CEN (mandate is in progress). The discussion came to the following conclusions:

- The framework TG compiles what it knows about product TCs developing product group specific documents as PCR. CEN Product TCs on their own initiative have already started to assess standards with a view of the product specific requirements of their products.
- the "basket" idea is promoted, which means that the full set of indicators describing the environmental performance of products is given on product level. Member states can then decide on the level of the building which building performance characteristics they consider essential and therefor should be provided on product level for their national regulation. This implies that CEN TC 350 rather will not select any indicators to cover main essential product performance characteristics.

However WG3 and TG will provide an explanation to CCMC which indicators should be correlated to which requirements of BWR7 and why in order to support CCMC's answer to DG ENTR. For BR 3 this should probably be climate change and the results of CEN TC 351. For BWR 7 it could be ADP, material and fuel for recycling, The net impacts described in Module D are very difficult to apply. They are recycling potentials already translated into potentially avoided impacts from different sources throughout the life cycle.

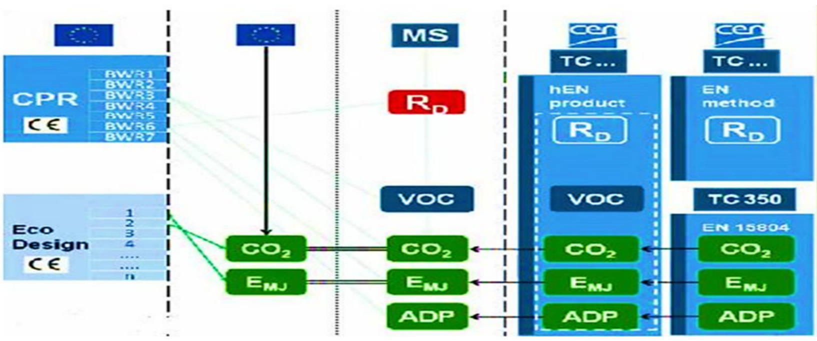

Image 2. The idea how to use of CEN TC 350 (and TC 351) indicators for CE marking [5]

BWR7 askes for recyclability, not future recycled content, which depends on ease of disassembly which is not directly represented in the LCA, especially when the disassembly is done by manpower.

The advantages of EPDs

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For industry EPDs provide opportunities for presenting a quantitative and verified information about the environmental performance of products, seen from a comprehensive life cycle perspective. The following advantages of EPDs should be underlined: comparability - because the information is collected and calculated based on EN 15804, neutrality – result is "as it is" without valuation, credibility - through the requirements for audit, review, approval and follow-up by an independent third party verifiers, accuracy - because the information has to be continuously updated. For industry the internal added value is considered as:

- Higher transparency in manufacturing regarding environmental aspects and impacts
- Possibility of optimisation own production processes
- Knowledge about own production impact in comparison to the competitors
- Knowledge of product influence on building environmental performance

External and global benefits for industry are:

- New dimension in communication to the End Users (B2C) and to business (B2B)
- New dimension for promoting product in a direct marketing competition
- Important part of the building environmental assessment
- Addresses new sustainable requirements from CPR
- Support green public procurement
- Support environmental protection process by offering the benchamark

Unfortunately from the consumer point of view there are also week points of such a way of presenting the product environmental information. There are studies performed by consumer organizations conducted with the view to defining the potential relevance of EPDs to consumer information [4]. Those interviewed were consumers who were committed to improving consumer information. Some studies suggest that EPDs are in the tradition of product-related data sheets, but have to be conditioned for the purpose of consumer information and to be "translated" into a format understood by the consumers. Inadequate clarity and absence of comprehensible evaluative information have been the most important points of criticism.

Environmental assessment information (MND – Module not declared, MD – Module Declared, INA- indicator not assessed)																
Product stage			Construction process		Use stage							End of life				Benefits and loads beyond the system boundary
Raw material supply	Transport	Manufacturing	Transport to construction site	Construction-installation process	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction demolition	Transport	Waste processing	Disposal	Reuse-recovery-recycling potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
MD	MD	MD	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND

Environmental impacts: 1 m²				
Indicator	Unit	Producer 1	Producer 2	Producer 3
Global warming potential	[kg CO_2 eq.]	13,4	16,5	18,77
Depletion potential of the stratospheric ozone layer	[kg CFC 11 eq.]	5,24E-07	1,48E-06	8,35E-06
Acidification potential of soil and water	[kg SO_2 eq.]	0,044	0,057	0,06
Eutrophication potential	[kg $(PO_4)^{3-}$ eq.]	0,0034	0,0059	0,007
Formation potential of tropospheric ozone	[kg C_2H_4 eq.]	0,049	0,0039	0,007
Abiotic depletion potential (ADP-fossil fuels) for fossil resources	[MJ]	316,54	290,5	394,1

Image 3. EPD based environmental profile for 1m^2 of ETICS (3 different producers)

A certain demand for information can be satisfied by EPDs when it comes to consumers with a particular interest in the environment, in other words, consumers who are used to process and classify information. It is this category of consumers for whom EPDs have the potential of adding value to the information so far available. The usefulness of the EPDs for consumer information might be improved by enhancing them to the level of environment-related product data sheets. EPDs can just as well be regarded as an information basis for experts (Image 3), although the latter would again have to translate such information for the consumers. Beyond this criticism there are alsopositive votes. Thanks to EPDs, more aware customers and business know the environmental impacts of products over lifetime and this information can be used for design and construction process where better environmental solution is considered. Customers have the assurance that the statements are not green washing marketing. Based on the data provided by the EPDs, customers can improve the sustainability of their value-added chain and can demonstrate the environmental awareness.

Conclusions

The demand for environmental declarations and their number grows. Without harmonized procedures for verification it will be difficult to use EPDs to support legislation, CE marking, design process and construction. Without harmonization process in across Europe the added value for EPDs can be relatively small. The process to introduce EPD harmonization program is set to move quite quickly following the finalization of ECO platform work to rationalize the various EPD approaches in the EU. Important experiences were discussed in the article.

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Session 125:

Are empty spaces the best opportunity within cities?

Chairperson:
García Madruga, Carolina
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Stop, Reassess and Redesign: Resilience assessment within contexts of Urban Regeneration Strategies

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Abstract: *Urban Regeneration and Resilience have become crucial tools for Sustainable Urban Development. However, although Built Environment Sustainability Assessment Systems have driven innovation regarding such development vision, they have not focused on the former issues. This investigation advances the rethinking of such assessment systems, in the light of systematising a 'Resilience-oriented Urban Regeneration Assessment Framework', which assesses sustainable regeneration interventions, at the community scale. This investigation (1) explores the general characteristics of Resilience and Urban Regeneration, (2) compares the approaches of existing assessment systems and accordingly (3) proposes a new assessment framework. This investigation should be understood as an initial milestone in trying to suppress the identified void. Thus, while proposing the backbone of a potential assessment framework for 'Resilience-oriented Urban Regeneration', this research emphasises the need for a 'fresh approach', as existing methodologies do not comprehensively assess Resilience in Urban Regeneration contexts.*

Keywords: Urban Regeneration (UR); Resilience; Sustainable Urban Development (SUD); Built Environment Sustainability Assessment Systems (BESASs)

Introduction

Sustainable Development (SD) represents a shift in understanding the relationship between 'Society' and the 'Environment' [1]. Thus, as cities have become favoured proponents for SD [2,3], urban planning has drawn on the strands of 'place making', 'environmental responsibility', 'social equity', and 'economic viability' [4]. Built Environment Sustainability Assessment Systems (BESASs) have become instrumental at driving innovation, as support tools for such processes of Sustainable Urban Development (SUD) [5,6]. Additionally, 'Resilience' [7,8] and 'Urban Regeneration' (UR) [9] have lately been emphasised as crucial components of planning processes that focus on SD within urban environments. However, scientists have only recently begun to tackle 'Resilience' [7], while BESASs have neither deeply focused on 'UR processes', nor have they rehearsed the potential assessment of 'Resilience', as a crucial component of a 'strong urban sustainability', i.e., of a '*systems-based approach to urban sustainability, which emphasises that the human sphere is embedded in a natural system and assumes the overall preservation of natural capital, over time, while supporting possible increases in human capital*' [10,11].

Managing 'Resilience', i.e., managing the '*ability of an urban system to absorb disturbances and change by (1) fostering self-organisation, (2) building and increasing the capacity for learning and adaptation', while essentially (3) retaining its basic functions and structure*' [7], has become an important feature for promoting 'Sustainability' [8]. UR, as a '*comprehensive and integrated vision and action for the long-lasting resolution of urban problems and improvement of the socioeconomic, physical, and environmental conditions of the target* *areas*' [9], can further tackle Sustainability and Resilience issues, while responding to arising needs and challenges. Therefore, this paper advances the rethinking of current BESASs, in the light of promoting Resilience in UR, through the systematisation of a 'Resilience-oriented UR Assessment Framework' (RURAF), which can tackle the assessment of these interventions in SUD contexts, at the community scale. In this setting, 'Sustainability' becomes the '*advanced-state in which a balanced set of local social, economic, and ecological patterns is achieved and maintained within the same structure, function and feedbacks, in a dynamic temporal and spatial frame*' [based on 12].

The first section of this paper explains the general characteristics of Resilience and UR that subsidise SUD. The second section discusses the approach taken by existing BESASs to the potential development of broader urban scales, covering the assessment of Resilience and UR. The third section systematises the general characteristics for a potential BESAS that tackles Resilience, within UR processes, at the community level. This paper highlights the importance of a Resilience-oriented BESAS, the RURAF, focused on UR strategies, and of its contribution to tackle the assessment of SUD as a dynamic process for achieving a 'strong urban sustainability'. By examining and defining the assessment characteristics of a potential BESAS that focuses on Resilience-oriented UR, this investigation acknowledges and sheds light on the innovative assessment of dynamic, resilient and strong sustainable processes of UR, through BESASs.

Approaching Resilience and Urban Regeneration from the perspective of Sustainable Urban Development

The first step in understanding how the assessment of dynamic, resilient and sustainable processes of UR can be achieved with BESASs implies operationalising the principles of (1) 'Resilience' and (2) 'UR' within a (3) 'strong urban sustainability' perspective. The latter implies reassessing the 'triple bottom line' of Sustainability trough a more holistic and comprehensive vision for SD, proposed by Giddings et al. [13]. They suggest the 'nested circles' model where the 'Economy' (3) is nested within 'Society' (2), which is nested within the 'Environment' (1). SANZ [11] further emphasised that the '*Econosphere*' (3) is embedded in the '*Sociosphere*' (2), which is embedded in the '*Biosphere*' (1). The authors of this paper suggest adding two 'nested circles' to this vision, the first being the '*Locusphere*' (4), i.e., the '*Habitat*' or the place humans inhabit, which in this case is the 'urban environment', which is nested in the '*Econosphere*' (3).

The benefits of reinvesting in a redundant or derelict '*Locusphere*' are clear from a SD viewpoint, as contemporary UR has been developed as a holistic concept for the social, economic and environmental transformation of urban areas [9]. Tallon [14] has summarised the concerns of UR into five main categories, which respect and add to the 'nested circles' model: *'physical environment'* (1); *social welfare* (2); *economic prospects (3)*; *quality of life* (4); and *governance* (5). The later is suggested as the last nested circle, the '*Curosphere*' (5), i.e., the '*Government*' or the agents that manage the place humans inhabit, which is a management sphere nested in the '*Locusphere*' (4). This model suggests the five main categories of the proposed RURAF, which can be understood as: (1) Environmental Enhancement; (2) Social Welfare; (3) Economic prosperity; (4) Habitat Quality; and (5) Urban Governance.

The '*Locusphere*' can also be understood as a Social-ecological System (SES), i.e., a system composed of humans and nature, which is nested in higher-hierarchy SESs and nests lower-hierarchy SESs. Resilience can allow the embracement of *"the idea of adaptation, learning and self-organization in addition to the general ability to persist disturbance*" [15] in SES. SESs' Resilience can be described by [8]: (a) the amount of disturbance the SES can absorb and persist; (b) the degree of the SES's self-organization; and (c) the ability to enhance learning and adaptation capacity. 'Resilience Thinking' presents an approach to managing the 'Biosphere' that embraces human and natural systems as complex adaptive systems and is described by [7]: (a) the '*adaptive cycle*' and (b) the '*panarchy*'. Most SESs [16] proceed through recurring '*adaptive cycles*', consisting of four phases [7,8]: (a1) rapid growth - *r phase*; (a2) conservation - *K phase*; (a3) release - *Ω phase*, and (a4) reorganization - *α phase*. SES behaviour changes, from one phase to the next, as it's internal connections, flexibility, and Resilience change **[7]**. Every SES is also composed of a (b) hierarchy of linked 'adaptive cycles', operating at different spatial and temporal scales - the '*panarchy*' [8]. At each scale SES dynamics is driven by a set of processes interlinked with scales above and bellow, which ultimately govern the higher-hierarchy SES **[7]**.

In the context of operationalising Resilience in urban environments, several authors [8,17] have evidenced the importance of promoting: (a) diversity; (b) modularity; (c) independence of SESs components; (d) redundancy; (e) feedback sensitivity; (f) capacity for adaptation; (g) social capital; (h) innovation; (i) environmental responsiveness and integration; (j) ecological variability; and (k) maintenance of SESs services. Applegath et al. [17] have further suggested a set of urban principles to meet the conditions of a resilient urban SES. Moreover, Ginot [18] has elaborated a set of key regeneration strategies that promote and encourage a successful and sustainable UR. The authors of this paper [19] have previously elaborated a 'Sustainable support framework for resilient Urban Regeneration' (SFUR), i.e., a framework for UR that focuses on achieving higher levels of sustainability, through Resilience promotion in urban SES. All the former perspectives and their general objectives have been recombined by the authors of this paper in order generate the subsequent sections ('*themes*' and '*sub-themes*') of the proposed RURAF, which, in conjunction with the formerly proposed '*categories*' and later suggested '*good design practices*', form the backbone of the suggested framework (see Table 1).

Table 1 - Categories, themes, sub-themes and good design practices of the proposed RURAF.

Category	Theme	Sub-theme	Good Practices
Environmental Enhancement	Local Integration	Land Use	Promote sustainable land use, while reinforcing compact development.
		Natural Ecosystems	Support ecological preservation, valorisation and biophilia.
	Resources	Energy	Sponsor renewable energy sources and energy efficiency.
		Water	Encourage water efficiency and sustainable water management.
		Local Sources	Boost and encourage the usage of local resources.
	Environmental Impacts	Waste	Endorse 4 Rs waste planning (reduce, re-use, recycle and recover).
		Pollution	Stimulate air, light, thermal and noise pollution mitigation.

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Social Welfare	Community Enhancement	Social Capital	Promote well-developed social networks, and local sense of belonging.
		Human Capital	Develop the local stock of human competencies, knowledge, and skills.
	Community Provision	Local Provision	Improve the provision of basic social services, housing and utilities.
Economic Prosperity	Economic Dynamism	Diversity	Enhance local economic diversity and labour opportunities.
		Integration	Stimulate cooperation and integration between local economic entities.
	Economic Development	Development	Endorse entrepreneurial activity and create new economic centralities.
		Innovation	Encourage local innovation and knowledge networks and systems.
Habitat Quality	Designed Communities	Place-making	Create strong, vibrant places, enhancing local heritage and landscape.
		Changeability	Promote adaptability, modularity and upgradeability of urban modules.
	Friendly Communities	Mobility	Sponsor pedestrian-friendly environments and sustainable mobility.
		Safety and Security	Guarantee local safety and security conditions.
Urban Gover-nance	Governance and Engagement	Local Governance	Promote sustained governance and sustainability awareness.
		Local Engagement	Require the active participation of community members, at all scales.
	Management	Local Management	Stimulate the sustainable management of local urban constituents.

Assessing Resilient-oriented Urban Regeneration Processes through BESASs

The ability to identify key aspects of Sustainability is a crucial factor in supporting and evaluating SD, which is reflected in the aptitude to develop and secure such key aspects in urban SESs and access, recognise or certify them [20]. Over the last two decades, BESASs have become instrumental at driving innovation regarding Sustainability issues and promoting SUD [5,6]. The area of 'environmental assessment of built environments' has matured remarkably quickly, since BREEAM was first introduced in 1990 [6], with a rapid increase in the number of available BESASs and their sub-versions worldwide [5,6,20]. In Portugal, LiderA was developed in the mid-2000s, to specifically consider the Portuguese context, reflecting the different Portuguese standard practices, culture and environmental issues [20]. However, despite significant advances BESASs are yet to comprehensively [5,6,20] grasp 'UR scenarios and processes' and rehearse the potential assessment of 'Resilience', as a crucial component of a 'strong urban sustainability'. Moreover, given the wide array of available BESASs worldwide, choosing the right methodology(ies) to access Resilience in UR contexts, becomes a 'mammoth task', as their goals, scopes and focuses vary significantly, while the amount of available versions is now overwhelming.

In this context, this investigation has (a) compared 27 BESASs worldwide and has (b) defined the five most highly-rated systems, illustrative of each of the four represented continents (America, Asia, Europe and Oceania) and of the national context (Portuguese origin). This comparison was based on five criteria extrapolated from the principles referred in the previous section: (a1) *scope* – regional, national or international – BESASs that evidenced more assessment scopes ranked higher; (a3) *scale of assessment* – buildings or communities - BESASs that covered both ranked higher; (a4) *land uses assessed* (available versions) – housing, offices, retail, education, mixed-uses - BESASs that covered all ranked higher; and (a5) *utilisation of the assessment frameworks* (completeness of vision, measurability, comprehensiveness, applicability and availability) - BESASs that covered all and were more 'user-friendly' ranked higher. The (b) five most highly-rated BESASs selected were: BREEAM (UK / Europe); CASBEE (Japan / ASIA); LEED (USA / America); LiderA (Portugal / National context) and Green Star (Australia / Oceania).

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The second step in understanding how the assessment of dynamic, resilient and sustainable processes of UR can be achieved through existing assessment systems implies reviewing and comparing the selected BESASs and understanding how (A) extensive (comprehensive and holistic assessment of the RURAF's *sub-themes*) and (B) operable (ease of application of the suggested assessment (by the BESASs) of the RURAF's *sub-themes*) was their approach to assessing Resilience in UR contexts, through the previously proposed RURAF's methodological backbone. Points were attributed on a scale of 0 to 2, with the later representing either that (A) the system fully covers the sub-theme scope or that (B) its assessment methodology is adequate and easy to apply. Consequently, this investigation compared the BESASs schemes that assessed the community scale, namely: BREEAM Communities (SD202- 0.2:2012) - BREEAM-C [21]; CASBEE for Urban Development (Tool-21 - 2007 Edition) - CASBEE-UD [22]; LEED Neighbourhood Development (2009 Edition) - LEED-ND [23]; LiderA Urban (V2.0 Urban 0.3-2011) - LIDERA-U [24]; and Green Star Communities (Pilot - 2012) - G-STAR-C [25].

This investigation (see Table 2) has established that overall LiderA-U is the most adequate scheme to directly access Resilience in UR contexts. It is also the scheme with the most adequate methodology to assess the *Local Integration*, *Resources* and *Environmental Impacts* themes. Moreover, BREEAM-C is the most adequate methodology to assess the *Community Enhancement* and *Community Provision* themes, while LEED-ND is the most adequate to assess the *Economic Development* theme. Furthermore, CASBEE-UD is the most adequate to assess the *Economic Dynamism*, *Designed Communities* and *Governance and Engagement* themes. G-STAR-C is the most adequate to assess the *Friendly Communities* and *Management* themes. The comparison of schemes also revealed which sub-sections are better and worst covered by existing BESASs. Existing BESASs comprehensively cover the assessment of *Land Use*, *Natural Ecosystems*, *Energy*, *Water*, *Mobility* and *Safety and Security*, failing to systematically cover *Local Sources*, *Integration*, *Development*, *Innovation* and *Changeability*.

Table 2 – Scheme comparison according to the sub-themes of the proposed RURAF.

Category	Theme	Sub-theme	BREEAM		CASBEE		LEED		LiderA		Green Star	
			A	B	A	B	A	B	A	B	A	B
Environmental Enhancement	Local Integration	Land Use	1	2	1	1	2	2	2	2	2	2
		Natural Ecosystems	2	2	1	2	1	2	2	2	1	2
	Resources	Energy	1	2	2	1	2	2	2	2	1	1
		Water	2	1	2	1	2	2	2	2	2	1
		Local Sources	0	0	1	2	1	1	2	1	1	2
	Environmental Impacts	Waste	0	0	2	2	1	1	2	2	1	2
		Pollution	1	1	2	1	1	2	2	2	1	2
Social Welfare	Community Enhancement	Social Capital	1	2	1	2	1	2	1	2	0	0
		Human Capital	1	2	0	0	1	2	1	2	2	2
	Community Provision	Local Provision	2	2	1	2	1	2	1	2	1	2
Economic Prosperity	Economic Dynamism	Diversity	1	2	0	0	2	2	1	1	1	2
		Integration	0	0	0	0	0	0	0	0	1	1
	Economic Development	Development	1	2	0	0	1	2	1	1	1	1
		Innovation	1	1	0	0	1	2	1	2	1	1

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Habitat Quality	Designed Communities	Place-making	2	1	1	2	2	2	2	2	2	2
		Changeability	1	1	1	1	0	0	1	1	1	2
	Friendly Communities	Mobility	2	2	2	2	2	2	2	2	2	2
		Safety and Security	1	2	2	2	1	2	2	1	1	2
Urban Gover-nance	Governance and Engagement	Local Governance	1	2	1	1	1	1	2	1	2	2
		Local Engagement	1	1	1	2	1	2	1	1	1	2
	Management	Local Management	1	2	2	2	0	0	1	2	1	2
		TOTAL SCORE	23/42	30/42	23/42	26/42	24/42	33/42	31/42	33/42	26/42	35/42

RURAF - A framework for tackling Resilience, within Urban Regeneration contexts

Considering that SD represents a shift in the relationship between 'Society' and the 'Environment' [1], in which BESASs have become instrumental as support tools for SUD [2,3], and that they have neither deeply focused on 'UR processes', nor rehearsed the potential assessment of 'Resilience', the need for a RURAF becomes pressing, especially when Sustainability becomes a collective goal. Thus, Resilience, as a crucial component of planning SD [7,8], becomes crucial to promote a comprehensive and holistic vision for a 'strong urban sustainability'. In this context, UR [9] can be understood as the potential strategic vision and action for implementing such urban development vision in existing urban environments. From this perspective, the proposed RURAF acknowledges the development conceptions behind a 'strong urban sustainability' by readdressing and expanding the 'nested circles' model [13] in a deeper vision for promoting SUD, through UR processes: the '*Curosphere*' (5) is nested in the '*Locusphere*' (4), which is nested in the '*Econosphere*' (3), which is nested in the '*Sociosphere*' (2), which is nested in the '*Biosphere*' (1), respecting the earlier suggested definitions of 'Sustainability' and 'strong urban sustainability'. Additionally, the comparison of the BESASs in the previous section has enabled this research to further elaborate the potential assessment '*criteria*' of the proposed RURAF, i.e., to elaborate the last potential level of the proposed assessment framework, which is suggested in Table 3. Table 3 summarises a potential backbone for the proposed RURAF, which takes into consideration the assessment methodologies and criteria of existing BESASs.

Table 3 – Potential criteria of the proposed RURAF.

Sub-theme	Criterion		
Land Use	Land Valorisation	Land Compactness	
Natural Ecosystems	Biodiversity	Biophilia	
Energy	Energy Management		
Water	Water Management		
Local Sources	Local Sources Management		
Waste	Solid Waste Management	Liquid Waste Management	
Pollution	Air Pollution Mitigation	Thermal/Light Pollution Mitigation	Noise Pollution Mitigation
Social Capital	Social Diversity and Mix	Social Inclusion and Interaction	
Human Capital	Education		
Local Provision	Service and Utilities Provision	Housing Provision	
Diversity	Economic Diversity and Mix	Local Labour	
Integration	Cooperative Systems	Integrated Systems	
Development	Entrepreneurial Activity and Investment	Centralities and Proximity	
Innovation	Local Innovation		
Place-making	Functional Diversity and Mix	Local Heritage and Identity	Landscape Integration

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Changeability	Adaptability	Modularity	Upgradeability
Mobility	Inclusive and Pedestrian Supportive Communities	Access to Amenities	Transit Supportive Communities
Safety and Security	Safe and Secure environments		
Local Governance	Sustained Governance	Sustainability Awareness	
Local Engagement	Participation and Involvement	Cooperation and Partnerships	
Local Management	Regeneration and Operation Management	Monitoring	

Conclusions

SD as a consequent shift in understanding the relationship between the '*Biosphere*' and the '*Sociosphere*' [1] should be pursued through a 'strong sustainability' perspective [7,8,10,11]. Thus, managing 'Resilience' becomes a crucial feature for achieving the ultimate goal of Sustainability. UR [9] has the potential to become the development vision and action to support such 'journey' in the '*Locusphere*'. The need for a RURAF is pressing on: although BESASs have become instrumental at driving innovation in SUD processes [2,3], they have neither focused on 'UR processes', nor rehearsed the potential assessment of 'Resilience'. This article should be understood as a modest milestone in trying to suppress such void. Consequently, this research has suggested the expansion of the 'nested circles' model [13] in a deeper vision for promoting SUD, through UR processes. By examining and defining the characteristics of a RURAF, this research has acknowledged the fundamental value of existing BESASs in assessing Resilience in such contexts. Nevertheless, in proposing the backbone of a potential RURAF, this research emphasises the need for a 'fresh approach', as existing approaches to BESASs need further development - they are still fragmented, uncomprehensive, difficult to apply in specific cases, and ultimately do not comprehensively satisfy the assessment of Resilience.

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Integration of Sustainability Issues into the Regeneration of Urban Wasteland: From Theoretical Framework to Operational Monitoring Tool

Abstract: *Regeneration of urban wastelands can contribute to revitalize and densify some portions of post-industrial European cities. A growing number of urban wasteland regenerations is now promoted by diverse territorial measures. However, it must be recognized that they mostly focus on "green constructions", leaving aside holistic aspects of the concept of sustainability.*

Indeed, due to the inherent complexity of these projects, achieving the objectives of sustainable development is not spontaneous. It depends upon a proactive search for global quality, integrated into the project dynamics, and a continuous assessment of sustainability tailored to these sites.

In reaction, this paper presents how a strategic integration of sustainability issues into urban wasteland regeneration projects can answer these targets. Preliminary research led to the creation of a theoretical framework, validated by a test application. Consequently, steps to transform this framework into an operational monitoring tool are presented. The resulting tool aims to concretely facilitate the regeneration of urban wastelands into truly sustainable neighborhoods.

Urban strategy, wasteland regeneration, sustainable neighborhood, sustainability assessment, indicator system, monitoring tool.

Introduction

As part of the polycentric and compact city model [1,2], the regeneration of urban wastelands is identified as a strategy to counterbalance the negative effects of urban sprawl. Indeed, it contributes to the densification and revitalization of the existing built fabric [3]. In this sense, several national European governments have developed policies and incentives to foster these projects [4,5]. Although increasing the number of wasteland regenerations is generally seen as a sustainable land take solution, these projects are not in themselves inherently sustainable [6]. Their revitalization and their densification is a "necessary but not sufficient condition" to encompass the environmental, economic and social dimensions of sustainability [7,8]. In addition, these projects must aim for a sound management of the process, in a holistic vision of sustainability. This fourth dimension facilitates a linkage between other dimensions and complements them [9].

With a land management perspective, recent tools propose *ex ante* approaches to wasteland regeneration in order to compare and prioritize sites for development or assess their potential [10,11]. Other studies have developed methods to assess the sustainability of urban wasteland regeneration projects but are still limited to check-list, procedural framework or single evaluation [12–14]. In all cases, these methods are dissociated from the complete project dynamics they cannot be applied on a regular basis or address all the phases of a project. Consequently, they cannot be qualified as operational monitoring tools.

In order to fill this gap, a tool is required for structured and continuous follow-up of these projects by integrating a search for global quality adapted to the regeneration of urban wasteland. In this respect, preliminary work as led to the creation of the SIPRIUS indicator system, a first theoretical framework for the integration of sustainability into the regeneration of urban wasteland [15]. Using this theoretical basis, a research project is currently conducted at EPFL [16] in order to transpose this framework into a digital monitoring tool for integrating sustainability issues into the project dynamics. This paper describes the main features of SIPRIUS and a test-application performed on a project in Neuchâtel, Switzerland. It also presents a milestone of this research in progress: the identification of an adaptable digital monitoring tool entitled OKpilot. The methodological steps to transpose the theoretical framework into the operational monitoring tool are then exposed.

Integration of sustainability issues

In general, urban wastelands are large scale areas cut off from their surroundings, occupied by different buildings of uneven quality and marked by a strong – often negative – identity (real or perceived contamination, sense of insecurity, economic and social stigma, cultural symbols, etc.). In addition, the complex process of an urban wasteland regeneration project is also singular: multiple stakeholders, important risks, long duration, evolution of conditions, overlapping of development phases, etc. This complexity makes the correlation between the regeneration of urban wastelands and sustainable development not automatically valid. Yet, without considerations of the holistic concept of sustainability, regeneration projects that appear successful in the short term might be the blighted areas of tomorrow [17]. Therefore, an operational assessment that contributes to the integration of sustainability issues seems necessary. To fulfill its role, operational assessment is understood as a “tailor made tool” adapted to the complexity of this type of projects. This is the only way to provide key stakeholders with an accurate overview of the situation [9]. The purpose is not to deliver turnkey solutions, but rather a decision-making tool to assist them in making informed choices. Therefore, requirements for an integrated operational assessment are the following:

1. Search for a global quality: The assessment covers sustainable development principles in a broad and holistic way, i.e. environmental, sociocultural and economic aspects are evaluate in addition to a sound project management. For exemple, the latter includes citizen participation, transparency of information and collaboration between stakeholders.

2. Adaptation to specificities: The assessment is adapted to the above-mentioned specificities of urban wasteland regeneration projects (scale of the project, various building types, etc.).

3. Inclusion of monitoring principles: The assessment is structured and continuous. It allows clear visualization of different stages of the project in order to follow and act on performance trends.

Theoretical framework

Building on these requirements, preliminary work has resulted in the development of a comprehensive framework entitled SIPRIUS [15]. The methodology leading to its creation is based on three successive steps.

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First, the selection of criteria is divided in two categories to represent the large scale and multidimensional aspects of wastelands: 1) criteria that refer to the context, which implications go beyond the site's limits, and 2) criteria that refer to the project, which influence stays within the site's boundaries. Criteria are distributed evenly among environmental, social and economic aspects.

Second, indicators are selected to assess each criterion following fundamental rules [18]: completeness, relevance, sensitivity, objectivity, accessibility and readability. Indicators also take into account several types of buildings.

Third, in order "to measure" and give "value" to each indicator, reference values are allocated. Four reference values are available: Limit Value (V_L) or "veto value", Average Value (V_A), Target Value (V_T) and Best Practice Value (V_B). These values are achieved incrementally, that is to say by "levels of performance". Results, both qualitative and quantitative, can be measured and compared without using any numerical aggregation.

Altogether, SIPRIUS is composed of 9 criteria and 21 indicators relating to the context and 12 criteria and 21 indicators relating to the project. Concurrently with the creation of the indicator system, a conclusive test application was performed on the Ecoparc neighborhood in Neuchâtel, Switzerland. The assessment of this wasteland regeneration project has allowed to make iterative improvements and practical settings as well as to validate the adequacy and the relevance of SIPRIUS. As an exemple, Figure 1 and 2 show the results of environmental, sociocultural and economic indicators for context criteria and project criteria. These synoptic tables, based on qualitative aggregation of the results, provide a clear and synthetic view of different indicators, at different stages of the project. Comparison with the initial situations (context criteria) or with the initial objectives (project criteria) is also facilitated.

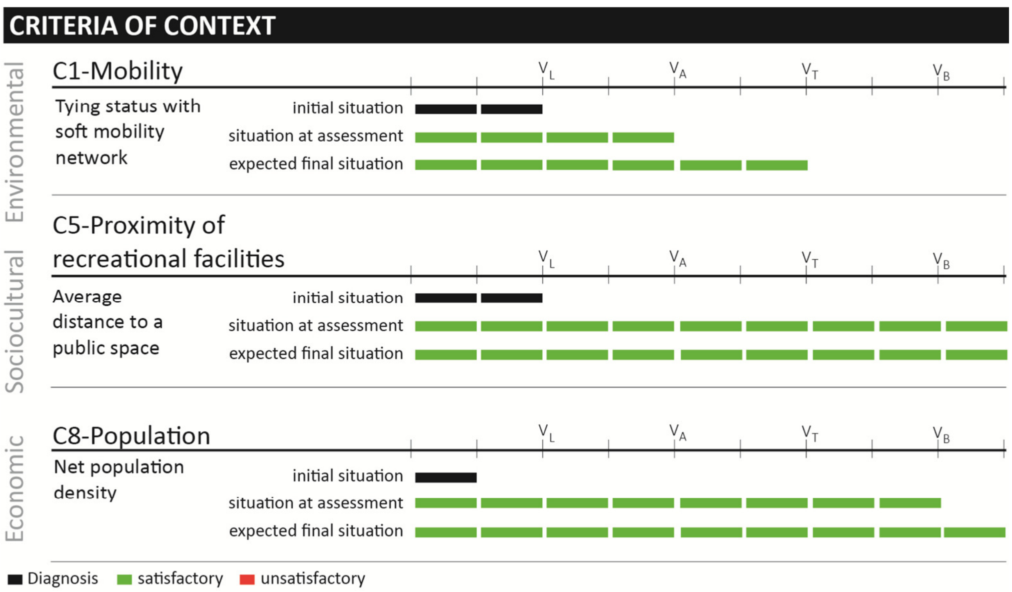

Figure 1. Results of the SIPRIUS test application on the Ecoparc neighborhood (Neuchâtel, Switzerland). Selection of three context criteria.

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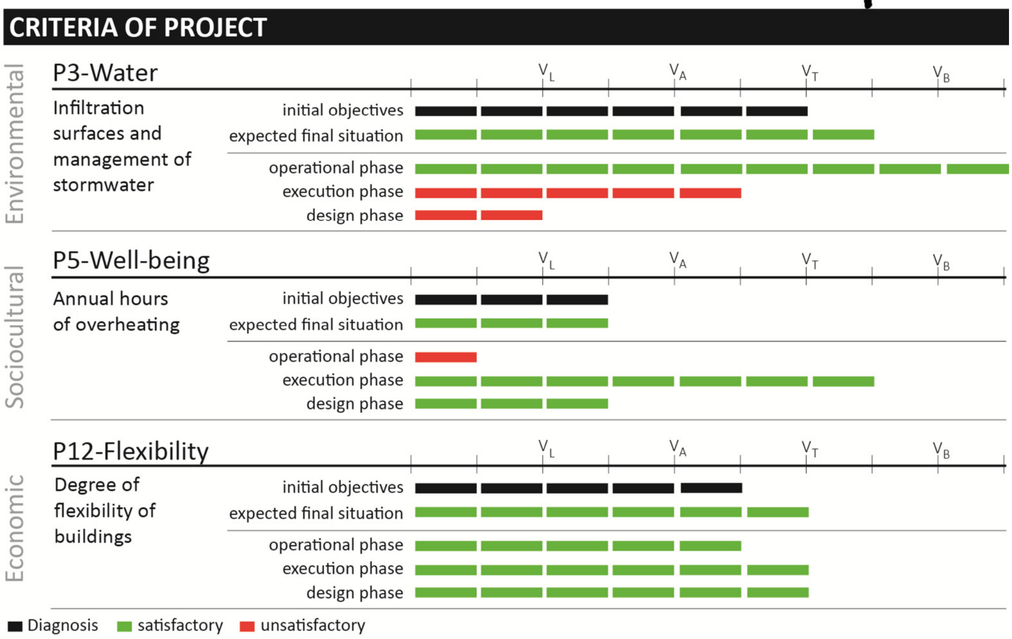

Figure 2. Results of the SIPRIUS test application on the Ecoparc neighborhood (Neuchâtel, Switzerland). Selection of three project criteria.

The test application has demonstrated that SIPRIUS fulfills most of the requirements for an integrated operational assessment. It covers the three primary dimensions of sustainability in a search for global quality and is adapted to the specificities of this type of projects. In addition, it sets the basis for monitoring principles with the measurement method based on reference values and the results expressed in a synoptic table.

The test application shows that SIPRIUS contributes to draw attention on sustainability issues within a project. However, the use of the framework can be cumbersome due to the large number of indicators. It can be limited by the level of involvement and interest in the assessment of key stakeholders. In order to generalize its use, the ongoing research suggests transposing this existing theoretical framework into a digital monitoring tool that could support the management and the communication of the project's performance.

Identification of an existing digital monitoring tool

Digital monitoring tools are used in many diverse fields where the management of sustainability issues is needed. Even though indicators may differ, methods employed for sustainability monitoring in business, in a public services or in development projects have considerable similarities. Consequently, instead of starting from scratch, it appears relevant to use an existing monitoring tool as a basis.

For the purpose of identification of an appropriate tool, required properties are described below. In general, the tool must allow *ex ante, in itinere* and *ex post* assessments and give simultaneously overviews and precise pictures of the project performance, at different stages. More precisely, it must provide a structured database and integrate both qualitative and quantitative indicators. It must help to make iterative improvements to the project according to the results of the assessment. It has to be applicable to a variety of urban wasteland regeneration projects and extended to the general practice. Finally, simplicity of the monitoring tool is required: it must be easy to operate by a project leader as well as to make reports and to communicate the results to a majority of stakeholders from various background, from professional to citizen groups.

An analysis of various digital tools allowed us to identify a web-based monitoring solution called OKpilot. It offers structured and continuous assessment throughout the project process and holds the required qualities. OKpilot is a user-friendly sustainability monitoring tool for businesses and public communities. It is a SaaS (Software as a Service) platform which ensures smooth implementation, simple maintenance and lower operating costs [19]. The technical feasibility in order to convert OKpilot toward the field of the built environment has been confirmed through a preparatory test. From this information, particular adaptations – presented in the following chapter – were identified in order to make the two systems compatible.

From theoretical framework to operational monitoring tool
With the objective of integrating sustainability issues into urban wasteland regeneration projects through an operational monitoring tool, the research project is organized around three major key steps:

1. Adaptation of the theoretical framework: SIPRIUS needs to be updated in order to meet the current and future challenges of sustainability in a search for global quality. These include aspects relating to a sound project management by the addition of criteria relating to the process (public consultation, transparency of information, etc.). Besides, reference values refer mostly to the Swiss context; they need to be adapted to different countries in order to match case studies (key step n.3).

2. Adaptation of the monitoring tool: This fundamental step implies particular adaptations so that OKpilot meets SIPRIUS' needs. Two of them are of strategic importance.

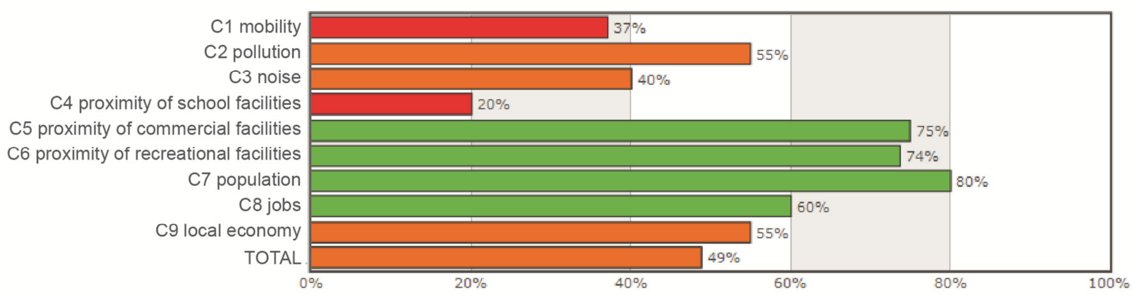

Figure 3. OKpilot - Results are displayed in a standard histogram

The measurement method used by OKpilot is based on relative values: the results of an assessment are expressed as a percentage. Computer programming is needed to develop and include absolute values to the measurement method. This is necessary in order to be able to compare results based on levels of performance (reference value system: Limit, Average, Target and Best Practice Value).

OKpilot displays the results of an assessment using a standard histogram with continuous bars for each criteria. (cf figure 3) In this regard, an adaptation of the graphical representation is also needed in order to include the synoptic table developed for SIPRIUS (cf figure 1 and 2). It displays incremental values which represent the level of performance for each indicator.

3. Case studies: The third key step consists of case studies selected in Belgium, France and Switzerland. Indeed, these three countries are concerned by the phenomenon of urban wastelands and direct their land use policies toward their regeneration at different levels.

Conducted in parallel to the adaptation of the SIPRIUS system, this step will contribute to feed the framework in an iterative way as well as to optimize and validate the monitoring tool by taking into consideration practical needs in relation to the integration of sustainability issues in concrete urban wasteland regeneration projects.

Discussion

By means of an adaptation work validated by case studies, a new operational monitoring tool with its own specificity in terms of content and its own identity in terms of presentation will be developed. This tool aims at answering the requirements of an integrated operational assessment by including a search for global quality and monitoring principles, both adapted to urban wasteland regeneration projects.

The research aims at facilitating the integration of sustainability issues in the project dynamics by providing useful bases to stakeholders; urban wasteland regeneration projects then become neighborhoods with increased sustainability. This objective is translated in an operational monitoring tool applicable to a multitude of projects of this type.

In the long-term, a fourth step will include a verification of the usability of both the tool in day to day situation and the outputs. In addition, this step – performed with the potential users – will allow validating the identification of the primary target audience of the operational monitoring tool (private property developers, public developers, local authority, professional advisors, etc). This usability phase will be included in the planning of the research underway at EPFL.

Conclusions

Sustainability is not inherent to urban wasteland regeneration projects, therefore an adapted operational monitoring tool is necessary for its integration. The SIPRIUS theoretical framework sets the basis for an operational assessment. In parallel, the digital monitoring tool OKpilot is identified as suitable to SIPRIUS' needs as it offers a structured and continuous assessment of the project. Three key steps are described in order to develop the operational monitoring tool: the adaptation of the theoretical framework, the adaptation of the digital monitoring tool and the validation through case studies. The operational monitoring tool is expected to contribute to the integration of sustainability issues into the regeneration of urban wasteland and by consequence increase the sustainability of resulting neighborhoods. Further work suggests the inclusion of a usability phase. Research is now starting with the adaptation of the digital monitoring tool.

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Impact of social sustainability assessment tools in the early planning phase of refurbishment and infill development

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Abstract: *The paper presents the results of case design studies based on town planning sustainability strategies and the use of social assessment tools for communal involvement. The focus is on social aspects in the early design and planning phase in accordance with the Life Cycle Stages of construction works in the EN 15643-3 framework for assessment of social performance, standardized by the European CEN/TC 350 technical committee – "Sustainability of construction works".*

Social assessment, sustainability, town planning, refurbishment

1 Introduction

Strategic measures have been taken in Europe to tackle the challenges of redeveloping built environments for a sustainable future. However, the targets for the social dimension of sustainability are loosely defined and tools are still developing. [1]

The paper presents the results of case design studies based on town planning sustainability strategies and the use of social assessment tools for communal involvement. The focus is on social aspects in the early design and planning phase in accordance with the Life Cycle Stages of construction works in the EN 15643-3 framework for assessment of social performance, in the European CEN/TC 350 standards - Sustainability of construction works.

The paper is based on work within the national Finnish project KLIKK – *lähiöiden käyttäjä ja liiketoimintalähtöinen korjauskonsepti* started in 2012 and ending in 2014. The goal of the project is to develop a user and business-oriented renovation concept for the refurbishment and extension of suburban apartment buildings. Suburban infill development and regeneration models have been studied in 6 different case studies in the Finnish towns of Kouvola, Porvoo and Turku. The design work has been supported by researchers from Finnish universities and research organizations, along with numerous industry partners and representatives for the town planning of selected cities. The focus has been on a participatory design process aiming to highlight the potential for urban renewal in our Finnish suburbs and neighbourhood units. From an industry viewpoint the target is to develop an all-inclusive refurbishment concept. [2]

2 Case studies Kouvola

The participatory early stage design process was studied in depth in two cases in Kouvola, the northern and southern parts of the Kasarminmäki and Kaunisnurmi area.

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Kouvola is a south-eastern Finnish town with about 87 000 inhabitants, after a municipal merger in 2009 [3]. The town structure varies from rural to urban, with about 60% of the inhabitants living in the urban town area. Work on a development strategy for central Kouvola was started in 2011 and resulted in a master planning vision for 2030, published in 2013. [4] The main focus is on developing the central town areas, including refurbishment and urban infill projects, aiming for 1500 new apartments in the town centre. [5]

The case study area of Kasarminmäki and Kaunisnurmi is a residential area located within walking distance of the town centre, with about 950 inhabitants. The area is heterogeneous with the oldest buildings dating from the 1800´s. To the north the area is bounded by the old Russian garrison area of Kasarminmäki (1911-1914), an Orthodox church built in 1913-1915 with a surrounding park including the original main gate to the barracks quarter from 1923, designed by Alvar Aalto. The Sakaristontie road represents idyllic 1950´s town planning. [6] Kaunisnurmi is divided into northern and southern parts by the Kuusaantie road, which has heavy traffic with a daily average of 30 000 cars. The parts of the area closest to the south side of the main road represent 1960´s town-planning with multi-storey buildings that mainly date from between 1960 and 1969. [7]

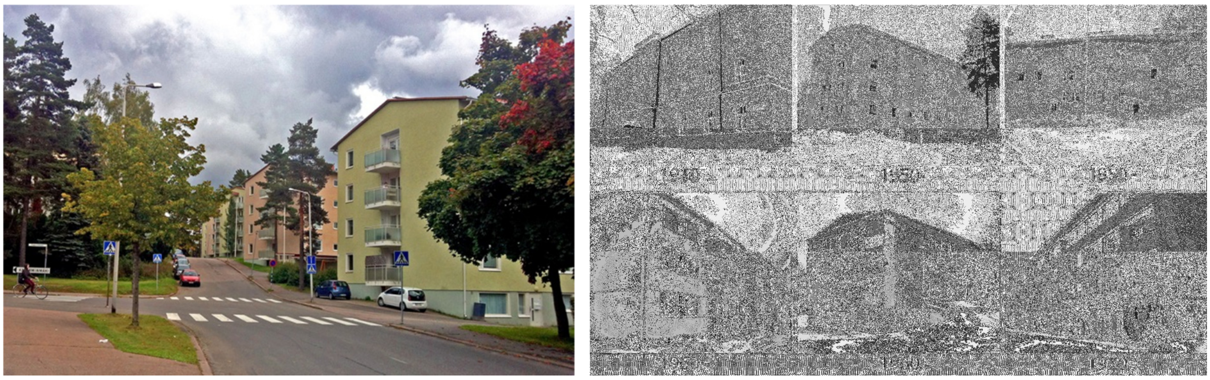

Figure 1: Sakaristontie street and Kaunisnurmi building typologies 1910-1970 (photos S. le Roux, L.Harno)

2.1 Fostering participation in design

Two design projects were realized for the area, one focusing on the northern part and one focusing on the southern parts close to the Kuusaantie main road. The aim was to design the infill of new housing aiming at promoting greater diversity among the inhabitants, focusing especially on the housing needs of families with children. The aim was for an inclusive design process based on participatory elements. The work was realized as a collaborative process including the entire neighbourhood of Kaunisnurmi. The participation of local inhabitants and stakeholders was initiated and encouraged on several levels including face to face interviews, on-site analysis, online tools including a project website, social media and a web-based questionnaire employing a *softGIS* participative geographical information system.

The goal of a multi-channel approach to participation was to reach a local demographic representation of different age-groups and backgrounds. Social media and online tools were employed to maintain interest with quick responses, ease-of-use and to save time processing answers. The innovative use of new technology and multimedia reinforced a message of a

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contemporary approach to development master planning. The *softGIS* survey was answered by 81 respondents giving over 500 located observations. In order to encourage a broad response, it was necessary to make personal contacts, pin announcements to noticeboards and contact the local press. (Figure 2)

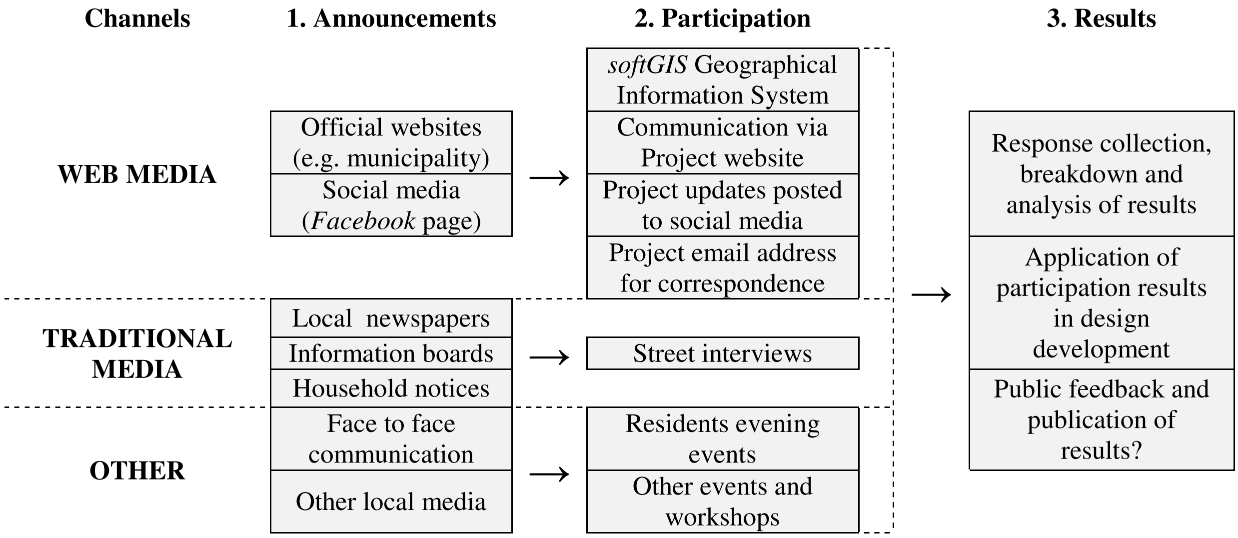

Figure 2: The design process in the Kouvola case employed multiple channels to initiate residents' participation in the Kaunisnurmi and Kasarminmäki neighbourhoods (after L.Harno 2013)

3 Methodology in social participation

European standard EN 15643-3 provides a framework for the assessment of social performance of buildings. The purpose of a standardized framework is to enable the comparability of the results of sustainability assessments integrating the environmental, social and economic performance of buildings. The main focus of the assessment of social performance in the planning and design stage of a building life cycle is on the issue of stakeholder involvement at all scales, including building users, neighbourhood impacts and within the greater society. This standardized framework does not describe the evaluation process or set benchmarks for levels of social performance, but refers to the EN 16309:2014 standard to provide specific methods and requirements for the assessment of social performance on the building level. Only six of the assessment categories of social performance given in the EN 15643-3 framework have an agreed basis for standardized calculation methodology at this time, i.e. Accessibility, Adaptability, Health and comfort, Impacts on the neighbourhood, Maintenance and maintainability, Safety and security. Two further assessment categories have not yet been deemed to be ready for standardization in EN 16309:2014, specifically the Sourcing of materials and services, and Stakeholder involvement. Methodology is defined for evaluating functional and technical characteristics in the use of a building, but the methodology for assessing stakeholder engagement in the decision-making process remains to be defined.

According to institutionalized democracy it is important to achieve consensus, and stakeholders' participation is required by law in town planning process. The Finnish Land Use

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and Building Act (132/1999) for example, demands participation, interaction and impact assessment. Design objectives for broad based stakeholder participation are set out in theoretical assessment frameworks, but methodology is diverse or missing. In practice there still remains a great gap between designers and residents. There may be great deal of participation, but only a little interaction. [8] In comparison to institutionalized legal processes, grassroots participation is informal and allows designers to explore alternative methodology to stimulate residents' interactions at early design stages, rather than just listening to opinions and reducing complaints after a design has for all intents and purposes already been fixed. The main objective is to find methods to share knowledge.

3.1 Interdependence of media channels and participative GIS

The case study in Kouvola provides good examples of an exploration into methodology for stakeholder participation. The combination of traditional media channels, innovative use of social media and personal contacts demonstrated the interdependence of media. Respondents were found to be surprisingly active, and by using both traditional and social media it was possible to steer respondents to a project based participative GIS internet based survey.

The *softGIS* methodology provides a spatial framework to analyze qualitative and quantitative observations to support the planning of contextually sensitive urban densification. [9] This stakeholders' internal perspective gave outlines and direction to inform the design process and analyze alternative scenarios, and helped to counterbalance the designers' external perspective and challenge design preconceptions. From the start, it was necessary for the designers to have a sympathetic attitude to participation, rather than being defensive against outside interference. Respondents' data required careful analysis, but it was possible to track the demographics of responses. A vocal minority or a NIMBY attitude may dominate in a participative process, so under-represented groups need to be reached through other channels. Senior citizens, for example were under-represented in the *softGIS* and *Facebook* responses, and it required more traditional media for them to be reached.

4 Analysis of GIS survey results

The results collected from the GIS survey and presented by Harno and Lautanala in their thesis works identified respondents' values associated with specific locations: underused places with potential for redevelopment or change, negative associations, important places to protect and enhance the significance of functions and local services. Respondents were surprisingly positive to proposals for urban infill, refurbishment, and expressed a desire to attract new residents into the neighbourhood. (Figure 3)

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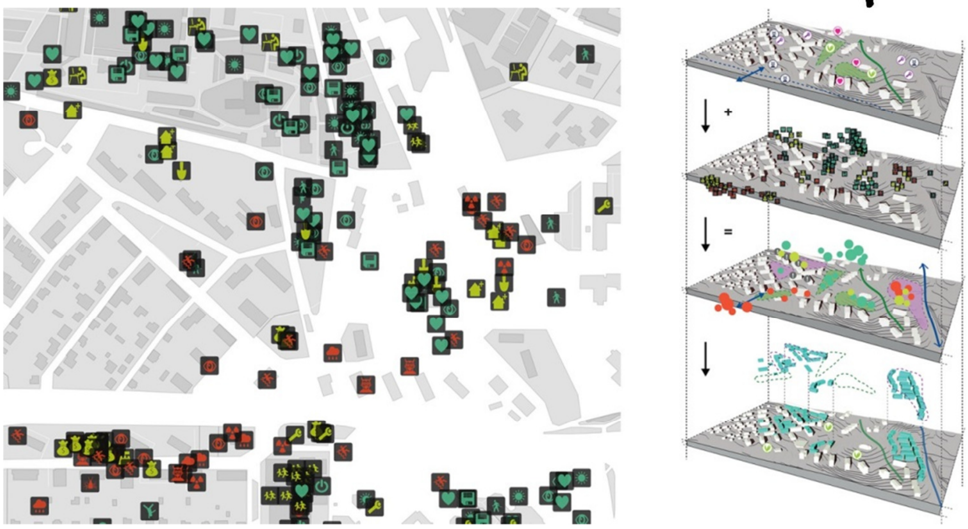

Figure 3: Respondents' softGIS observations of their living environment and local service, recreation areas, positive and negative associations, and locations suitable for conservation, development. On the right is visualized the overlay of a townscape analysis, the softGIS survey and a design proposal synthesis (L.Harno, Master's Thesis, 2013)

The case study location is valued for being within convenient walking distance of the Kouvola town centre, adjacent to an attractive museum quarter and educational facilities. The area has potential for an influx of aging residents due to the existing stock of small apartments in good proximity to a variety of services, but there are urgent needs to meet requirements for accessibility, for example with lifts to be retrofitted into multistory apartment buildings. Different needs of different population groups created some generation gaps in the area, where younger people hope for stimulating recreation and pastimes, and elderly need new facilities for assisted living and street furniture. City officials and residents both observed that new residents were necessary to maintain and attract services, but population growth remains limited in the area, although the neighbourhood is potentially attractive to new residents. In order to attract young families there should be a diversified supply of housing types with larger apartments, play areas and an improved standard of life.

The case study area has a monotonous housing typology in a loose urban structure, and residents' needs have changed over the past 50 years. The Finnish urban ideas from the 1960´s and 1970's suggested the milieu of a country villa in a forest, up scaled to small multistory apartment buildings separated by strips of forest parkland. This forest city ideal has become dysfunctional due to the increasing encroachment of private cars. [10] Green spaces remain undefined, eroded by growing traffic, and are seen as surplus reserves for development. The remainders of forest and the landscaped garden city are no longer logically combined, and lack a thematic hierarchy. Residents in Kaunisharju and Kasarminmäki wished for pleasant courtyards, new street furniture, maintenance of green spaces, and a clear identity for their built environment. The public realm and urban structure in the case study area was seen as being loosely defined. The designers proposed a hierarchy and specific themes to enhance green spaces, and proposed a new urban shopping park adjacent to a rundown shopping centre. Connections between buildings and street space needed improvement, and

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pedestrian safety and accessibility needed to be improved, giving common spaces priority over parking. There was a strong response requesting reorganization of parking areas and increased efficiency in street parking. It was concluded that it would be possible to infill housing and increase density by enhancing the quality of urban environment.

At the scale of individual buildings there was a research goal to promote refurbishment, to introduce life cycle thinking to architecture, repair facades, retrofit lifts and increase energy efficiency, and update the functionality of accommodation for current needs. [11] Design proposals for infill included a mixed typology in a "modern village" to diversify the supply of apartments. The wooden museum precinct is a popular local attraction, and a precedent for new timber construction in a predominantly concrete and red-brick built environment. A small scale typology of housing could be added, to create intimate landscaped courtyards.

5 Discussion and Conclusions

A case study in participative design realized within the national research project KLIKK is presented. The case work resulted in proposals for infill development and urban regeneration of the selected areas. The cases exemplify different approaches to stakeholder involvement in a participatory design process for urban infill development and remodeling taking into account residents' points of view, visions and needs. The variety of stakeholder participative methods included face to face interviews, workshops, on-site analysis, and various interactive on-line tools with websites, social media and web-based GIS methods. The results highlight the different needs of age groups and social impacts of our built environments. The work was also guided by city representatives. The city perspective includes economic goals as well as environmental impact assessment. The proposals for infill and regeneration are mirrored against standardized sustainability indicators, for an insight into the relevance of social indicators for stakeholders at different levels of assessment.

The conclusions drawn from the Kouvola case studies were structured in more concrete terms than the abstract categories in the standard framework for the assessment of social performance in buildings. The performance indicators related to accessibility, adaptability, health and comfort, neighbourhood impacts, maintenance and maintainability, safety and security are relevant and emerged in many responses and proposals, but are overlaid and unevenly distributed throughout the area, and findings within these categories are associated with specific locations, services and infrastructures. Assessment standards are specific to the functional unit of buildings, but the overarching principles of sustainability pertain to interrelations which are spatial (accessibility, and neighbourhood impacts), temporal (maintenance, adaptability), material (life-cycle impacts) and social (services, health, comfort and safety). Principles are applicable on different scales, but design decisions are a unique synthesis of observations and trade-offs between priorities in problem solving. The creation of new built areas is typically visionary in nature, whereas the design process and implementation of urban regeneration or renovation projects is complex and based on numerous drivers and interests when aiming for an environmentally, economically and socially sustainable future.

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Urban agricultural typologies and the need to quantify their potential to reduce a city's environmental 'foodprint'

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Abstract: *Presently, the supply chain supporting urban food consumption is placing stress on the environment at the planetary, regional and local scales. Despite the urban origin of global food demands, cities supply little of their own food, and are susceptible to disruptions across the global supply chain. One possible mitigation strategy to these issues is increasing food production in and around cities using urban agriculture (UA).*

Through a literature review, we found claims surrounding UA as a way to attenuate a cornucopia of environmental burdens due to urban food needs, but that their veracity remains inconclusive. A comprehensive analysis of the environmental performance of dominant UA forms is therefore needed. However, the review also found paucity in meaningful systematics that described UA systemsbased on attributes important to environmental performance. We addressed this by developing a system that categorizes UA into five broad types that are optimized for comparing environmental performance.

urban agriculture, urban metablism, foodprint, life-cycle assessment, urban resilience

Introduction

Global urban population is growing along with development and wealth of many cities and the citizens therein. Cities now contain more than 50% of humanity, and this percentage is only expected to increase into the foreseeable future [1]. Urbanization is also typically linked with increased wealth and resource consumption [2], making the environmental pressures produced by cities discordant with the populations they support [3].

The food consumed by cities has been identified as one of the key consumption categories in terms of influence on urban environmental performance, with the environmental pressures related to urban food *demands* labeled *'foodprints'* [4]. The urban metabolism approach to urban systems analysis has presented itself as an ideal lense with which to assess foodprints, since it endeavours to quantify the sum material and energy demands of a city, typically including food [3]. In recent years, efforts to link urban metabolism with environmental footprinting techniques, such as ecological footprint (EF), carbon footprint (CF) and life-cycle assessment (LCA) have highlighted the importance of the urban foodprint in the discussion of sustainable urban development.

A recent CF of eight US cities identified the urban foodprint as the third largest contributor overall to the cities' impacts at an average of 13% [5], while a study of urban household consumption in Beijing identified food demands as the single largest CF driver [6]. EF

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assessments are copacetic with these findings, often identifying the foodprint as the largest contributor to a city's EF, e.g. for London [7], Vancouver [8] and Sao Paulo [9]. LCA foodprints have also shown that urban food demands are pivotal in a city's environmental performance [3]. The importance of the foodprint in overall urban sustainability can be traced to the types of foods that urban dwellers consume (meat and dairy), the supply chains that support cities (e.g. 'food miles') and the mismanagement of food related waste in cities [3].

The urban foodprint represents an important area to improve urban environmental performance. This can be done on the demand side by changing the types of foods consumed by urban dwellers through incentivizing low impact diet choices [10] or minimzing food waste or on the supply side through improving the ecological efficiency of the food system supporting urbanites. UA (loosely defined as 'food production in and around cities') falls in to the latter category, and it is increasingly seen as a potential tool to be leveraged by cities to reduce their foodprints and strengthen local food supplies (e.g. New York City [11]).

Literature abounds with a veritable buffet of claims regarding the positive environmental implications of UA to climate impacts, urban nutrient recycling, noise pollution, stormwater flows, biodiversity, and others [12]. However, many of these claims are not fully supported, leaving numerous questions about UA's foodprint reductions potential [13,14]. Moreover, UA exists in a variety of forms (in cities, on buildings, at the edge of cities) yet there is a lack of systematics differentiating between these forms in terms of their environmental performance.

This study addresses these data gaps by performing a literature review to assemble the enviornmental claims regarding UA and assess the extent to which these claims can be justified. We will then begin to outline a typological framework for UA systems that lends itself to application in the realm of quantitative sustainability assessment (QSA), such as LCA, CF, EF and material flow analysis (MFA).

Method

A literature review was performed by accessing scientific and public electronic databases in order to identify literature relevant to UA's sustainability and existing schemes to classify UA varieties. The review was indiscriminate in document type, and therefore, peer-reviewed papers, conference proceedings, books, project reports, governmental reports, theses and magazine articles were assessed, though the focus was on peer-reviewed material.

From December 2013 to January 2014 a series of 13 UA relevant keyterms (e.g. 'urban greenhouse', 'urban foodscapes', 'urban agricultural life cycle assessment', 'urban agriculture typologies', etc.) were used to mine 15 databases (e.g. ISI Web of Science, Google Scholar, Oxford Journals, science.gov, Technical University of Denmark's library, etc.)

Relevant documents were then dissected to determine, (i) what sustainability claims are being made in connection to UA, (ii) support of these claims through field demonstrations and/or models, and (iii) existing UA typological frameworks. Once the absence of a UA systematics relevant for assessing UA environmental performance was identified, we developed a system

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to fulfill this role using literature on the QSA of both UA and general agriculture (e.g. LCA, CF, EF, industrial ecology), as well as the opinions of experienced experts in the fields of architecture, food LCA and urban sustainability.

Findings

The search yielded a total of 114 documents for perusal. The search mirrored other UA studies in finding that there was a large number of studies espousing the positive environmental impacts of UA [13,14]. Claims concerned impacts from the local scale (heat island attenuation, dust suppression, local air quality improvement) to the global (global warming mitigation, non-renewable resource conservation). Table 1 outlines these claims found in the UA literature reviewed. It also provides a breakdown of the presented quantitative support for these claims. It should be noted that quantitative support was considered as either fieldexperiments or predictions from rigorous models, but not rough estimates.

Table 1. Summary of environmental claims and supporting literature found in the review. Not an exhaustive list of all of the reviewed material, but a summary of relevant findings. Bold references indicate UA field tests.

Sustainability Claim	Quantitative Support
Reduction of CF	
-food miles [12,15]	-Local production around Osaka, JP could reduce embedded energy in vegetables by 77% [30]
-carbon sequestration [16]	-CF reduction modeled for UA in the UK, benefits quickly neutralized by UA growing infrastructure [23]
-other	-Packaging savings potentially reduce CF with rooftop UA in Barcelona, ES [24]
Increased Eco-Efficiency	
-water conservation [17,18]	-Osmosis filtration and rainwater capture satisfied water needs of greenhouse barge off Manhattan, US **[25]**
-nutrient recycling [19]	-Wastewater recycling performed in African UA **[26]** -Historical wastewater recycling in Paris, FR contributed significantly to UA [27]
Improved Biodiversity [12,16]	-None encountered
Reduced Urban Heat Island [13]	-Satellite models showed appreciable heat island effect reduction in NYC, US with hypothetical UA scenario [22]
Local Air Quality Upgrading [20]	-None encountered
Soil Erosion Prevention [21]	-None encountered
Reduction of EF [19]	-None encountered
Building Energy Reduction [22]	-Simple model showed 41% heating energy reduction with rooftop UA in northern climate [28] -Modeled energy reduction of 23% for cooling and 20% of building integrated UA in Toronto, CA **[29]**
Stormwater Attenuation [22]	-Slowed runoff rate and reduced total runoff from building integrated UA in Toronto, CA **[29]**

Many of the claims made by UA advocates are supported to varying degrees by quantitative assessments of some kind, and therefore move beyond pure conjecture. However, a number of shortcomings make it difficult to extrapolate the supporting literature’s findings to support broader statements regarding the ability of UA to reduce urban foodprints.

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1. Where quantitative analsysis is present to support a claim, it has only assessed a single type of UA, thus making it uncertain as to how different UA forms might comparatively perform on the same environmental indicator;
2. Results limited to context of specific urban setting were assessment performed;
3. Some claims had a complete lack of studies to support them, with conclusions made a priori. For instance the assumption of reducing soil erosion is based on UA freeing up agricultural land outside of the city and allowing it to return to its natural state, a scenario that is all but guaranteed in the globally trading agricultural system which will have an increasing population to feed;
4. Assessments focused on one area of envirommental impacts, and therefore, tradeoffs in performance between metrics were ignored (except for [24]). Particularly a near ubiquitous focus on reducing transport distances of food ('food miles') ignores the fact that transport is *very often* of minimal contribution to a food supply-chains overall environmental impacts [31].

Conclusions surrounding the environmental benefits of UA remain murky at best, and assessments are required to determine; (i) how different UA systems compare environmentally, and (ii) what are the tradeoffs between different types of environmental impacts when switching from conventional food supply chains to UA.

To address these data gaps, the predominant UA types have to be elucidated and an assessment methodology applied to them. Clarifying the UA types was found to be difficult after a thorough review of the UA literature had been performed. This was a result of the propensity for socio-economic attributes (e.g. household income, gender of UA practitioner, etc.) and crude topological criteria (e.g. size, location in urban region) to be used in defining existing UA typologies (see [32] for example). Though these UA traits are no doubt essential to judging other aspects of sustainability, they are not functional towards evaluating environmental performance.

Environmentally Relevant UA Typological Framework

In reviewing current UA literature we found large variation in the UA systems utilized (e.g. rooftop greenhouses, vacant lots, etc.). The main goal of the environmentally relevant UA typological framework communicated here is to aggregate similar systems based on the likeness of their material and energy usage patterns, since these factors are related strongly to the ecological burdens of a system [33]. Moreover, the ease of different UA types to affect these patterns through integration with residual urban material and energy flows was considered as *Industrial Symbiosis Potential.*

Using this rationale, five unique and dominant UA types were identified; (i) ground-based, non-conditioned (GB-NC), (ii) ground-based, conditioned (GB-C), (iii) building-integrated, non-conditioned (BI-NC), (iv) building-integrated, conditioned (BI-C), and (v) living-machine (LM). Conditioned refers to a space separated from outdoor elements with controlled

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settings (temperature, humidity, etc.).Table 2 outlines the material and energy needs of the systems, and provides examples of UA methods that fit within the developed systematics.

Table 2. Attributes and examples of environmentally relevant UA types. 'high, medium and low' refer to potential differences between UA types, all other variables the same (crop, location, packaging, transport, etc.)

	GB-NC	GB-C	BI-NC	BI-C	LM
Substrate	**soil**	**soil or hydroponic**	**soil**	**soil or hydroponic**	**soil, water or hydroponic**
Nutrient Supply	**artificial, imported, high losses**	**artificial, imported, low losses**	**imported or self-supplied, high losses**	**imported or self-supplied, low losses**	**self-supplied, unknown losses**
Pest Control	**high**	**low**	**high**	**low**	**low or high**
Irrigation Needs	**climate dependent**	**low (w/ recycling)**	**climate dependent**	**low (w/ recycling)**	**none**
Energy Supply	**passive solar**	**solar or grid based**	**passive solar**	**solar, grid based or building supplied**	**solar or grid based**
Infrastructure Inputs	**low**	**high**	**low**	**high**	**very high**
Industrial Symbiosis Potential	**low**	**low**	**medium**	**high**	**high**
Cultivation Period	**seasonal**	**year-round**	**seasonal**	**year-round**	**year-round**
Examples	**vacant lots, community gardens, allotments, peri-UA**	**greenhouses (peri or central)**	**rooftop gardens, green walls**	**rooftop greenhouses**	**vertical farming, aquaculture**

The material and energy needs of the UA systems vary widely. Of particular note are the conditioned systems which may have an advantage by virtue of internal recycling mechanisms to capture nutrients and water, while at the same time protecting crops from pests and weather damage [18]. At the same time, conditioned systems require much higher material inputs in the form of permanent infrastructure (greenhouse structure, circulation systems, etc.), with their own embedded environmental burdens from manufacturing. Moreover, building-integrated UA forms distinguish themselves from the ground-based counterparts through the degree of 'industrial symbiosis' they can achieve with the urban environment, either through direct water or nutrient capture, or by influencing the energy use of the buildings with which they are fused [25]. Lastly, the 'living machine' types are intended to adhere to ecological principles of circular energy and material flows, and are envisioned to have very low external demands for these [18], however, the embedded environmental impacts of the associated built infrastructure could be significant.

Conclusions

Literature shows that UA does hold potential to reduce the foodprints of urban dwellers in some instances, but the conclusions are opaque. Foodprint reduction potentials from conventional urban food supply chains could be significantly different between UA forms for the same product. Moreover, it remains to be seen if a given UA form can reduce the environmental burdens of urban food demands for a given agricultural product, as the potential may exist to exasperate burdens if UA is used out of context (e.g. growing greenhouse tomatoes during the winter as opposed to importing them from a temperate climate). The UA typological framework developed provides a foundation to begin answering these questions using QSA methods and provide information to actors regarding the foodprint reduction potential of UA. Lastly, assessing the city-wide foodprint mitigation of intensive, city-wide UA proliferation will require a combination of these methods with urban metabolism to gauge if UA can make meaningful contributions to overall urban sustainability and urban food system resilience.

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Session 133:

Active citizens. How can we empower citizens for sustainable rehabilitation?

Chairperson:

Verdaguer, Carlos

Profesor Asociado. Escuela Técnica Superior Arquitectura Madrid, UPM

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Tenant involvement in renovation for low energy performance

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Abstract: *The general goal of tenant involvement is to ensure that retrofitting projects are successful not only from a technical point of view but also from a social perspective. When possible, strategies should be included to reward users for energy efficient behaviour. Energy monitoring and feedback are tools in support of energy savings. But how do users use these tools and what is the effect? In this paper chosen strategies in three pilot projects within the EU (FP7) BEEM-UP project, were accounted for together with previous studies of metering and feedback systems. The results were based on interviews, discussion among the project partners, measurement data and a literature study. The conclusions were that there are great variations in households' consumption levels which shows a potential for energy savings where the introduction of individual metering and feedback systems are examples of supportive methods even though the anticipated savings might not always be realized.*

Key words: *Multi-family housing, energy efficiency, energy savings, monitoring and feedback, individual metering, user behaviour*

Introduction

Approximately 40% of the EU's total final energy use (i.e. delivered energy) stems from residential and commercial buildings, responsible for 36% of the EU's total CO_2 emissions. Hence, it is important that the building sector takes its responsibility to reduce its energy use. Implementing technical energy efficiency measures in our homes is of great significance. However, in order to exploit the full potential of reducing the energy use, we need to broaden our view and complement technology development with user perspective and behavioural questions. The energy related behaviour influence to a great extent the gap between the potential and actual energy efficient levels [1]. Of importance is to apply strategies to influence the behaviour of end-users – the tenants.

The work has been carried out within the BEEM-UP project[1], which is an EU project in the Seventh Framework Programme (FP7). The aim of the project is to retrofit existing buildings so that the energy consumption is drastically reduced with a specific goal of reducing the space heating by 75%. The project includes long-term commitment to energy savings and stimulates the owners of the estate to monitor the energy performance and to give feedback on energy use to the tenants also after the retrofitting has been completed. The project follows the processes in three demonstration projects, namely Cotentin Falguière in Paris (F), Van der Lelijstraat in Delft (NL) and Brogården in Alingsås (SE). This paper reports on previous

[1] BEEM-UP stands for Building Energy Efficiency for Massive market Uptake, see www.beem-up.eu.

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studies of monitoring and feedback systems in relation to energy saving behaviour, as well as chosen strategies in the three pilot projects. Methods used were interviews with tenants in Delft after the retrofit, participation in the pilot application of new tools for monitoring and feedback systems in Delft and Paris, analysis of measurement data from consumptions in Alingsås and literature studies on the effects of these applications, as well as discussion among the partners involved in the BEEM-UP project.

Households' energy use - Individual metering and visualisation and feedback

The residents of a building influence to a great deal the household electricity and the hot water usage. They also influence the energy for heating to some degree by choice of indoor temperature and window airing habits. To increase the visibility of households' energy usage is one energy efficiency measure a housing owner can implement.

Individual metering and billing usually means that each tenant's consumption of electricity, gas, heating/cooling and domestic hot water is metered and paid for by the individual. Each resident takes economic responsibility for its own consumption [2]. This is also a matter of fairness; that you actually pay for what you consume. Metering the electricity consumption is standard in most countries, but metering heating (or gas/oil), including domestic hot water, varies from country to country. By June 2014 the EU Directive on energy efficiency [3] shall be implemented in member states. It states that metering of the consumptions by end-users must become standard in 2016 in order to reach the European Union's energy target to improve the energy efficiency by 20% by 2020 [4]. However, there are different experiences on the actual energy savings of individual metering, and especially in regards to heating (e.g. [2]). Berndtsson [5] investigated a number of Swedish projects and found savings of 10 - 20% on heating and 15 - 30% on domestic hot water, although there were great variations between households. A large German study, conclude that experiences from previous studies indicate that savings for heating is potentially 20% or even higher [6]. However, it has also been noticed that savings for heating were not obvious [7] and in later follow-ups, even the expected savings of domestic hot water were not gained [8]. Nevertheless, it is of interest that many studies show that the total water consumption is higher (per person) for apartments than for single-family houses were you to a greater extent pay your own bill [8].

In modern society, energy is very much a commodity that people are more or less unaware of. It is in many cases just delivered to our homes. By visualising the use of energy, people can be made aware of their own impact while providing them with an opportunity to change their behaviour. Visualisation of energy consumption in housing has been evaluated, for example in [9-14]. It has been shown that real-time metering and displaying support tenants' awareness of their electricity consumption. However, it has also been shown that it is difficult to keep the interest for energy visualisation alive at home [13, 15].

Feedback is linked to visualisation and there are many different kinds of direct and indirect feedback, such as in-house display devices, online information systems and informative billing. A number of different studies on feedback have been performed - an overview can e.g. be found in [12]. Individual field projects show a variety of results. A number of old and

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new studies on different types of feedback on energy consumption, some together with other behaviour changing tools, show that savings ranges from 8-27% [16]. More commonly referred figures ranges from 5-12% [17]. Other studies show none or small positive effect compared to reference cases [17-19]. Also Fischer [9] provides an overview of studies on feedback on electricity use. As an example, savings of up to a third of the electricity consumption have been measured when dormitory residents were exposed to real-time visual feedback and different incentives [20]. Finally, to fill the gap of evaluations of long-term results of home energy management systems (HEMS) a recent study by van Dam [21] discovered an initial peak in savings, that would fall back after some time. The average energy savings after some time were about 7%.

Chosen strategies and experiences in BEEM-UP pilot projects

The building of the Paris pilot project constitutes 87 apartments built in the 1950s and are owned by ICF Novedis. The energy feedback system used in the building is integrated in a videophone service that is also used as door opener, and as a communication channel between the housing owner Novedis and the tenants. On a display, data on daily consumption as well as on accumulated consumption is available. There are data on electricity, heating and hot water consumption which could be compared with previous days, weeks, months or years. There is direct feedback by figures (in Wh) and "smileys" to strengthen the message of more or less consumption compared to the previous time period. There have been discussions about showing indoor and outdoor temperatures but these have not been implemented yet. An external company was introducing the videophone and energy feedback service to the tenants by arranging workshops giving instructions as well as highlighting energy saving possibilities. The equipment is very new and a first evaluation will follow in about four months. There is no known previous evaluation of this particular design.

In the Dutch pilot project there are 28 attached houses and 80 apartments, which were built in the 1950s and are owned by Woonbron. A smart display is being used, working as a programmable thermostat and presenting real time and historical energy data and information about outdoor and indoor temperatures, heat and power consumption as well as information on the weather forecast. Comparisons can be made with historical data as well as with averages of the neighbourhood. The service comes from the energy company and the house owner is facilitating the first two years of use. During 31 interviews in Delft, that were carried out one year after the installations of the displays, some tenants indicated that insight in the power consumption had impact on the purchase of energy efficient lamps, on more selective use of the electric laundry dryer, defrosting of freezer and early replacement of refrigerator. The four set points of the thermostat function of the system were often used as an improved manual thermostat. In the first weeks after installation the tenants tended to check the historical energy data and also the power consumption quite often and they indicated a high learning curve. Then the activity tended to drop, depending on the level of interest in energy issues. The interviews indicated different reasons causing the fading interest. Some reached the end of a positive learning period, some were disappointed in the effect of their efforts to

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save energy and some had played enough with the new gadget and lost interest. An average positive effect on energy consumption has been reached, however. Further lessons learnt regarding the system were that the more reliable, transparent and understandable the feedback was, the more the user would take notice of the information. Also, these new systems were not (yet) robust enough and breakdowns with poor repair have caused that some tenants were either disappointed or did not even bother any more.

The whole housing area of Swedish project includes 299 apartments built in the 1970s and are owned by Alingsåshem. One of the main changes for the tenants related to the energy use after the completion of the renovation was that the hot water consumption and household electricity was individually measured for each apartment. Before the renovation both these consumptions were included in the rent. The common electricity and heating is measured per house. To clarify this formerly "invisible" cost is usually not done without any concern from the tenants and for that reason workshops were held in Brogården prior to the installations. It is a complex matter to compare the situation before and after the installation of the individual metering system. A number of energy efficiency measures were done within the renovation, such as the installation of energy efficient appliances as well as water saving fixtures. In one of the houses (18 apartments), an average decrease of 15% was achieved for the domestic hot water; the corresponding figure for all electricity (i.e. common and domestic electricity together) was 38%. In addition, more detailed measurements have been made in this house after the renovation, during a period of just over a year so far. The annual household electricity was measured to 21 kWh/m^2 (heated area). This is lower than a typical Swedish value, of 30 kWh/m^2 (heated area) [8]. Corresponding value for the domestic hot water was 23 kWh/m^2 (heated area) – typical value is 25 kWh/m^2 (heated area) [8]. Great variations in consumption were found between the 18 apartments, Figure 1 and 2. The largest domestic electricity was 3705 kWh/year and the lowest was 937 kWh/year, with a mean consumption of 2003 kWh/year. When the heated area of the apartments were considered one of the smaller apartments had the highest consumption with 61 kWh/year,m^2 and one of the larger apartments had the lowest consumption with 15 kWh/year,m^2. The coefficient of variation[2] was 44% (kWh/year) respectively 36% (kWh/year, m^2).

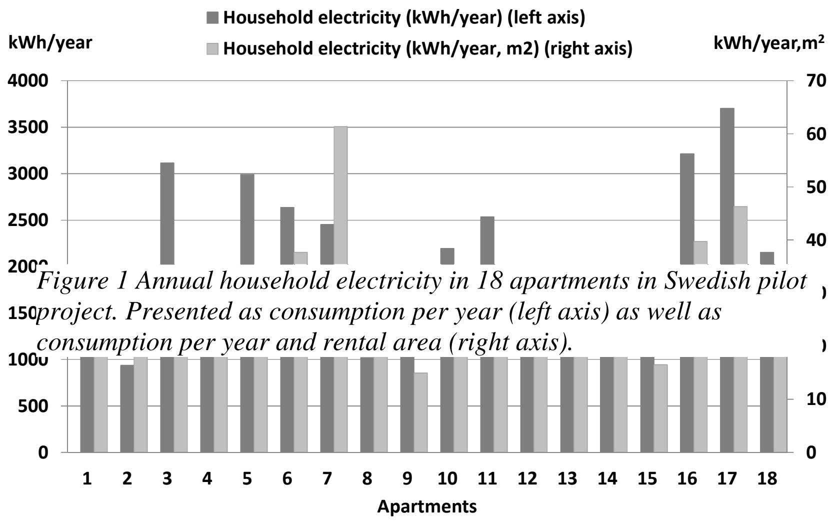

Figure 1 Annual household electricity in 18 apartments in Swedish pilot project. Presented as consumption per year (left axis) as well as consumption per year and rental area (right axis).

[2] Coefficient of variation or relative standard deviation is the standard deviation divided by the mean.

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The largest hot water consumption was 115 m^3/year and the lowest was 4 m^3/year, which is an extremely low consumption. The mean consumption was 38 m^3/year. Corresponding figures for when the heated area of the apartments were considered were 1.45 m^3/year,m^2 and 0.05 m^3/year,m^2, with an average of 0.54 m^3/year,m^2. The coefficient of variation was 78% (kWh/year) respectively 70% (kWh/year,m^2). No consideration has been taken to presence at home during the measurement period. It can be added that there was no strong correlation between the household electricity consumption and the domestic hot water consumption (the coefficients of determination, R^2, was 0.39).

Discussion and Conclusions

This paper highlights some examples of how housing owners can take further steps in energy saving measures and addressing households' energy awareness and usage. The three pilot projects of BEEM-UP have applied somewhat different strategies in this regard.

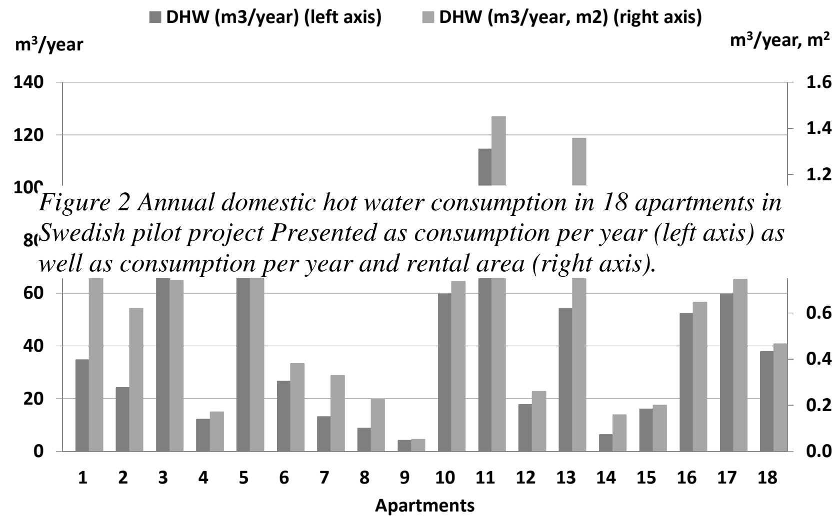

Figure 2 Annual domestic hot water consumption in 18 apartments in Swedish pilot project Presented as consumption per year (left axis) as well as consumption per year and rental area (right axis).

The French pilot project has just recently installed in-home displays where direct, real-time, feedback on consumption is given. Comparisons with historic data is possible and pedagogically presented with easy to understand symbols (the smileys). The displays have just been installed and have not yet been evaluated, but the multi-functionality of the display is believed to increase the prerequisite for usage. In the Dutch project, a home energy management system was used, which means not only a display but also the possibility to manage the indoor temperature by programmable thermostats. This turned out to be useful to some people as they could easily pre-set a decrease or an increase in temperature. Average energy savings are reached after the installation. There are both positive and negative experiences of the systems, such as positive effects on some energy related activities, but also the loss of interest and for some even distrust in the data. Breakdowns are of course not helpful in this regard. Long-term commitment is an issue to consider, which confirms results from previous studies. The importance of design and usability is another aspect to regard, which would increase the prerequisite for usage - however it will not mean a guarantee for savings. As all energy consumption was previously included in the rent, the first step in the Swedish pilot project was to start with the introduction of individual metering and billing. It will be of interest to follow the implementation of the EU Directive on energy efficiency in regards to individual metering and the effect – or non-effect – this will have on the households' energy related behaviour. From the previous field studies there seem to be a great potential for savings but the savings cannot automatically be presumed. How the energy usage, and also the energy savings, varies for different households is made apparent in the

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measurements in the Swedish pilot project. This confirms findings in previous literature [22]. The variations are even larger for the hot water usage. That water consumptions can vary greatly has also been found in previous studies – examples of variations of the total water consumption (hot and cold water) are found in [22]. Another interesting observation is that a low consumption of electricity does not mean a low consumption of DHW. Even though the number of persons is not known in this project, the variations in consumptions indicate that there are some potential for savings. Note that not all aspects of described energy saving tools have been considered, e.g. issues of cost calculations, split incentives, "heat thefts".

To conclude, to decrease the total use of energy in our buildings is a prioritised question where it is necessary that the end-users of the buildings also are involved. There are a potential of decreasing households' energy use - the way to do it is however not completely clear and multi-mode approach might be necessary. Individual metering and employment of feedback systems are examples of how the energy use can become more visible and increase the awareness of people and possibly lead to energy savings. However the expected energy savings might not be realized for a number of reasons. That the data and systems are reliable and robust is a good and necessary start. That the systems have multi-functionality is probably not a disadvantage for the frequency of usage. Just to mention some things. The long-term commitment still seems to be a challenge. In any case, in the end it might be a question of fairness - that we take responsibility for our own consumption of the resources of this earth.

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From the "project" to the "process" for the building rehabilitation. Intervention strategies on existing buildings at the times of crisis.

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Abstract: *The current economic crisis urges to put under discussion even the most recent cultural references and development models, and it forces to work according to the criteria of ever-decreasing use of resources, minimization of waste and maximum effectiveness of results, also when objectives of increasing sustainability in buildings are to be pursued. Consequently, in order to meet the new challenges, the traditional intervention strategies ought to be changed, especially in public sector.*

By the means of an experimental activity on a school, the paper shows how it is possible to develop intervention programs aimed at sustainable rehabilitation in the short to medium term, by diversifying the range of actions and by sharing work between owners and tenants responsible for their implementation. In addition, it highlights that the participation process in the evaluation of buildings in use is a great opportunity of increasing both awareness on sustainability and global empowerment of users.

Keywords, Sustainable rehabilitation, building retrofit, post occupancy evaluation, schools

Introduction

The massive development of major urban areas -that characterized Italy for a long time after the Second World War, so as many other European countries - has gradually waned over the last few decades of the twentieth century, leaving a large amount of increasingly older available building stock (not just residential). Moreover, the lack of culture and practice of routine maintenance, the continuous updating of mandatory technical requirements (on safety, energy saving, etc.), the change of the way of use and of the users' needs, make frequently inadequate or obsolete this range of buildings. Consequently, the necessity of interventions is supposed to increase more and more. In fact, the choise of keeping in use the existing buildings, instead of demolishing and replacing them with new development, can assure benefits in terms of saving of materials, containment of wastes and enhancement of energy incorporated in the building; but, on the other hand, it implies the necessity to take in charge their heavy loss in overall performance, and especially in consumption of non-renewable energy.

Many national and international research works were aimed to develop methods to detect, assess and solve technical and energy saving performance problems of buildings -like E.P.I.Q.R. funded by European JOULE II program in 1996-98 (1) -, or to pursue global environmental sustainability goals, by the means of certification programs and tools, like

GBC, BREEAM, LEED, etc.. Similarly, investment programs and job opportunities were produced, and helped to keep alive the construction industry in a recent past (2).

However, in the construction sector during economic crisis time, the contraction in investments tends to decrease work and innovation opportunities, and to increase the distance between the results in the field of research and the operational practice. Then, in order to try and stem the effects of this situation, and so guarantee adequate occupancy conditions, it could be appropriate to overcome the traditional process models for intervention on buildings in use, according to a different outlook.

Moreover, even if this problem involves both public and private buildings of every functional type; however, it becomes of particular importance when referred to the public facilities (for education, health, sport, culture, social housing, etc.), both because of their supporting social purpose, and of their not producing any revenue, which could offset the retrofitting costs.

In fact, authorities in charge of public facilities have deep responsibility towards all citizens, and, more than all, towards their specific users. They should therefore provide them, with places fully adequate to support their functional purpose; at the same time, they should also develop and promote good practices of management and intervention, aimed at enhancing the resources, reducing waste, promoting the well-being and comfort of the users, with a globally sustainable approach. Actually, when public bodies are supposed to manage large amount of facilities, including many buildings in widespread and varied conditions of physical and functional decay, they could probably meet more and more difficulty to cope with the multiplicity of needs and problems, and so, feeding an increasing dissatisfaction of the citizens. Such problematic situations occur and are highlighted especially on schools, where people become more "sensible", due to the inherent educational purpose in their function and to the presence of young users.

In Italy, school conditions are extremely varied, depending from their features (age, materials, size, target), and from management approaches and practice of local administrations, which have each own organizational autonomy. Nevertheless, the problems of the schools are large and widespread, but the resources allocated are no enough to solve them at all in a short time; so, the economic "stability pacts" imposed to administrations (according to the European objectives of financial stability) cause further investment contraction in the whole building rehabilitation works.

In the general issue of the schools retrofitting, nowadays the main focus is shot on health and safety problems (referring to fire, asbestos, structural issue, etc.), which necessarily absorb the ever scarce available resources of local authorities, due to the potential risks for people and of legal responsibility for the facility managers. All this, therefore, keeps making increase specialization and fragmentation of work processes (3), often developed in emergency or in a hurry, to repair faults or breaks; it also increases the centralization of building management and reduces the possibility of decision-sharing with occupants.

The ever less opportunity to develop plans of whole rethabilitation, makes, consequently more and more difficult to aim interventions at improving the school assets according to the principles of sustainability, if not through single works for energy saving (replacement of windows or boilers) or for deployment of renewable energy. Even for these latters, however, last funding opportunities are significantly littler than few years ago (4).

When the crisis strikes on a condition already problematic, it places in front of the need to change first those perspectives, through which the issues are looked at.

Generally, it should be expected that such important problems, like the school ones, will have to be widespreadly and definitively solved in a short time. Actually, this would require the starting of a number of works, in order to retrofit exsisting buildings inadequate in safety performance, in decay prevention, in their fitness for ever updated educational models and activities; and it would be to be pursued while ensuring users the school service, too. However, if such events did not take place in better times, still less it should be supposed that could happen in those worse ones. This does not imply the giving up the pursuit of these objectives or the reducing the economic and political commitments, that national and local institutions should take in respect of nationals -requests that are constantly renewed by citizens' organizations-, rather it means that all the institutional efforts will never be enough to ensure full achievement of quality and sustainability goals. (3, 5)

Therefore, in order to meet the new challenges emerging from the present crisis, the intervention strategies and models ought to be changed, in their objectives, resources engaged and tools. The traditional "project" should be integrated with new "plans" for "intervention and processes", with a various range of actions: those aimed at improving the way of use and the behaviors of users, those aimed at having building elements and systems working better, up to the most hard "building works". These processes should be able to go on over time, in stages, to meet ever changing needs and goals, in relation to the priorities, the operational conditions and the available resources, starting from the enhancement of the role of occupants.

An important contribution to head straight for this direction can be provided by research and applications on feedback activities; whose effectiveness -in order to adapt and improve building products and processes- has already been proved, since the early studies on Post-Occupancy Evaluation -POE (6) till to those on the whole Building Performance Evaluation – BPE (7, 8, 9,). Nevertheless, in Italy, despite the development of some experimental works (10,11, 12, 13), neither the clients (public or private), nor the professional associations have never promoted the feedback as routine activities.

The experimental activity

The opportunity of steering the processes of school management and interventions toward a sustainably-oriented approach by enhancing whole human and building resources has been tested through a post-occupancy evaluation activity, aimed at defining intervention strategies for a school, and carried out with the users' participation.

The case study was an educational complex in Milan (with a micro-nursery, a primary school and an afternoon school for adults), located in two contiguous buildings sharing a large courtyard, in really bad technical and functional conditions, for which the Municipality had just scheduled some urgent safety compliance works. Pending the availability of economic resources, it had also been designed a retrofitting project, without consulting any school references, so that many conflicts seemed to be emerging among the different stakeholders (school directors, teachers, students and families, facility managers , etc..). The evaluation activity had been promoted by the incoming school director, in order to gain a comprehensive picture of the problems and needs, related to the various educational projects and activities in place.

In accordance with the theoretical models, the evaluation process was based on the principle of the importance and the need of entrusting an active role to users of the buildings; both for their extensive and focused knowledge on issues, emerging from their experience; and because potential direct actors of following changes and improvements.

Indeed, this principle was promoted and shared from the earliest stages of planning the activities, with the aims of creating the conditions for an effective collaboration with users, gaining an overview of basic information on the buildings, on the groups of users and the activities, developing an operational program, and preparing the necessary tools for the planned activities. Then, the on-site performance analysis was developped with a multi-criteria and multi instrumental approach, in order to gather and integrate speedily different kinds of information and data, according to the objective of getting a good overall performance of the school. For this purpose, they were carried out a technical audit, an occupant survey, and functional & behavioral analyses.

The technical audit is the only activity carried out independently by technicians, in order to quickly observe and assess the overall quality of the buildings. It was to highlight all those decay conditions, broken elements or failed systems, and main building performance problems, which would have had the need of urgent interventions by the Municipality.

Nevertheless, in comparison with the traditional operating modes of the systems for public facilities management, much more significant and innovative were the activities of occupant survey and the functional & behavioral analysys. In fact, these activities allowed to develop a step by step process, of self-assessment, evaluation and sharing knowledge among several participants, as well as to outline a detailed picture of the problems, needs and proposals.

The occupant survay was developped through structured interviewes and a users' inquiry. Eleven special witnesses were selected and interviewed, becouse of their responsibility in various school activities or in educational special projects (for instance: entrance of foreign pupils, teaching to disables, extra activities for Roma pupils) or of their representing the teachers and the pupils' parents. The procedure involved a starting presentation of objectives and methods of the survey, which was followed by a set of questions aimed to focus on their activities and methods of working, on the various requirements referring to assigned places, on criticalilities, positive situations and the desired.

In the inquiry, were involved a variety of classes of users. Thus, different kinds of questionnaires were to be set and used, in order both to guarantee effective communication ways for all the participants, and to adequately balance the level of involvement in relation to their different roles. All the adults, who daily attend the school (as workers or students) were asked to evaluate the quality of various indoor and outdoor spaces, and to highlight problems and proposals, by the means of a classic questionnaire (6). The parents' representatives were invited just to list up to five problems, positive elements and desires. Eventually, the involvment of the eldest pupils of the primary school was supported by a special sheet template suitable for both writing and drawing, through which they were asked to highlight which were, in their opinion, the three worst and the three best elements of their school, and lastly to make suggestions for improvements.

By the functional & behavioral analysis, the spatial localization of all the activities, as well as the accesses and the connecting routes were mapped, in order to compare them with needs and problems just raised and also with regulatory requirements. Moreover, in order to pursue a more appropriate use of the spatial resources, frequency and intensity of use of some places were kept under observation, expecially of those intended for occasional activities and those at highest overcrowding.

Results

The work lasted an entire school year with a large participation of most of the various groups of users: primary school teachers (55%), pupils of the last year (100%), parents' class representatives (65%), teachers and students of the school for adults (not significant %). The results of each analysis activity were first processed separately, and later correlated. The picture of the organization and use of the school interiors (as it emerged from the occupant survey and the functional & behavioral analysis) looked particularly complex and problematic, as as a consequence of a succession of single decisions taken at random, over time.

Some courses (those for adults) had too little room and some others (primary school) were too dilated; some special classrooms were underused, because duplicated or assigned to occasional and/or no intensive activities (such as computer labs), as well other spaces were overcrowded (such as the refectory, due to the way of catering organization). The spatial distribution of activities was quite inconsistent with an effective functional relationship; the accesses were difficult to be kept under control and the different users' routes were all mixed; eventually many functional needs were not located. The irrational use of the available space, combined with the low energy performance of the building, involved a significant waste of resources. That happened because underused rooms were to be kept heated, cleaned, etc. for the whole working time; then, the continuous moving classes between the two different buildings caused further heat loss through open doors; moreover the overtime use of certain

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spaces (such as gyms, meeting rooms, etc.) was not provided with a proper sectioning of the systems and the routes, and so on.

All this, together with a rather inadequate organization model of some activities, caused significant conditions of discomfort, and even safety problems for users. However, it became evident that at the beginning, the survey participants were not ready to link those conditions of discomfort and dissatisfaction they were used to perceive, with the organization of activities and to the way they were accustomed to occupying the interiors. Their unconsciousness, however, could be in part justified by the overhang of the decay effects, due to a long absence of maintenance operations, as well as to the obsolescence of building elements, such as windows and heaters, and also to the state of neglect of the courtyard.

On the base of the evaluation outcomes, it was also produced a design brief for a retrofitting process, consistent with the objectives and the functional model of the school. Moreover, the most important result was the grow of the users' competence and awareness about the functional problems and the building care, that allowed both to steer previous bad behaviors towards better practice in the way of the building use, and to improve the interaction between the facility managers and the school direction staff.

Conclusion

As outcome of this experience, it seems possible to draw some conclusions of general interest.

It was verified that public authorities tend to operate alternately or in a random way (according to occasional priorities and availability of economic resources), or on the base of fixed projects, developed with little information, at the specific aim of calculating work costs and, consequently, of applying on calls for funding. In both cases, the decisions are not made on the base of (and/or verified through) any feedback outcome from participatory processes; nor they are oriented towards innovation, referring to education goals and to environmental sustainability. Moreover, due to the lack of available resources, often the implementation of these fixed projects is more and more long delayed and, as a consequence, its distance from users' needs and objectives is further lengthen. On the other hand, when resources are occasionally allocated for special purposes (such as fire safety, seismic risk, etc.), and the development of sub-projects do not take account of a whole vision, the rehabilitation works could possibly be at risk of incompatibility with subsequent and different goals and activities.

Therefore, it would seem appropriate to promote and develop continuous retrofitting processes with periodic steps of analysis and decision-making, so that the priority needs and goals to be funded could be verified and kept updated, always in accordance with a whole performance vision.

The continuous process model should be managed and supported by the means of shared protocols among various stakholders, as welle as of operative procedures, best practice promotion, actions aimed at removing bureaucratic obstacles, and so on. This would also result an arranged activation and exploitation of the vast treasure of human resources, which

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converge at the schools, and similarly at many other public services. Finally, this could prefigure the emergence of potential benefits, both in practice (by improving quality and identity of various places), and in people's empowerment, as way for increasing social commitment and shared responsibility, which are on the base of the culture of sustainability.

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Innovation on actions of citizen awareness in terms of energy saving in households

Abstract: *This article focuses on the citizen awareness campaign in terms of energy saving developed as part of the European project ELIH-MED*[3]*. The main objective of ELIH-MED is to identify and test, through large scale pilot actions, the feasibility of cost efficient technical solutions and innovative financial mechanisms in low-income housing in Mediterranean countries. The pilot action aims to energy retrofitting 500 homes, 56 of them located in 2 buildings in Valencia, which have been used as domestic laboratories.*

Launched awareness activities are exposed. They include both actions of active involvement of users in the studied households and actions oriented to mainstream audiences. Example of actions related to user involvement are face contact activities as, for example, personal interviews, surveys, or individualized energy reports, and, the examples of actions aimed at mainstream audiences are installing energy neighborhood kiosks or developing an online platform for citizen information on energy saving.

Keywords: environmental behaviour, behaviour change, energy efficiency, energy retrofit, home retrofit, home energy savings, campaigning and awareness raising, quality of life

BACKGROUND AND CONTEXT

According to several studies (1) nowadays it is clear that there is a growing interest of citizens towards sustainability, although this attitude does not always have a direct influence on the decisions of individuals as consumers. Lack of information is included among the reasons behind this behavior (2).

One of the most important actions of ELIH-MED project is framed in this context, where the Valencia Institute of Building, hereinafter IVE, is partner. Through this project IVE aims to work on information actions and public awareness, in order to raise awareness on the issues of energy efficiency in low income households, with active participation of inhabitants of the houses in the pilot projects designed. The influence of this campaign is intended to reach the regional and the national level.

ELIH-MED Project focuses on energy efficiency in low-income housing in the Mediterranean area in the context of the objectives of the EU 2020. The target population of the project are low-income tenants and homeowners suffering energy poverty and whose homes account for about 40% of the total housing stock in Europe. This population is considered difficult to reach through traditional public policy, so innovative technical and financial approaches are required in order to help them reduce their energy consumption. The project focuses on identifying and test the feasibility of cost efficient technical solutions and innovative financial mechanisms, which could then be extrapolated to other Mediterranean territories.

IVE pilot actions focus on improving two apartment buildings built around the seventies, with significant energy deficiencies, located in the expansion areas of the city of Valencia. Each

[3] Energy efficiency in Low Income Housign in the Mediterranean
http://www.elih-med.eu/Layout/elih-med/?page=/upload/moduli/pagine/public/project.asp&target=&tit=Project

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building has 28 homes, occupied by retired people by 70-80%. The proposed renovation focuses on improving the thermal envelope (roofs, walls and windows) and some aspects of the lighting of the common areas and of the elevator (detectors and LEDs). The works started in September 2013 and the completion date will be May 2014.

The result of this energy intervention will involve the transformation of these inefficient buildings, qualified in original condition with a letter G of the Spanish scale, in much more sustainable buildings of D class. As a result, residents of these buildings will see reflected this change in a reduction of their energy bills, as well as in the improvement of their quality of life thanks mainly to the thermal insulation installed, which will increase its acoustic and thermal comfort.

COMMUNICATION STRATEGY AND RESULTS
The goal is to show people, through different levels of action, the improvements derived from an energy retrofit process.

To design the Communication Plan, the audience it was intended has been taken into account as a premise, so the necessary tools to suit every level are established: local (for the people who live in the buildings and in the neighborhoods where pilots are located), regional (for municipalities in the region) and national level (for users in general).

Local actions

- *Design of training and dissemination materials* through a collection of 40 sheets of advice[4] on aspects of energy saving, color-coded to correspond to levels of investment. Three levels are established: An initial level for actions without costs identified in orange (like the use of natural light), a medium level for the middle economic investment actions identified in blue (like changing to more efficient lighting), and a high level of investment measures, identified in green (as roof insulation). The language used is simple, avoiding technicalities with clear information on investment and cost savings (3).

  The development of tip sheets makes tangible the advice and allows greater understanding by the receiver. These sheets were generated from feed back as some were made according to information needs identified in users.

- *Creating a monitoring committee* formed by a group of neighbors that actively participate in the achievement of milestones established for the developmetn of the energy improvement activities.
- *Calendar of meetings* established with the homeowners to inform them of the Pilot Action. Presence of interlocutors at meetings of the neighbors where the renovation works were in the agenda. Track progress of the refurbishment works at the site to address any questions and inquiries from neighbors. The active participation of the homeowners has made the people more compressive as they have been aware of the complexity of administrative

[4] http://www.buildup.eu/tools/34384

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processes. Also, people's acceptance of behavior change is often depending on how involved they feel they have been in the decision (4).

- *Development of a questionnaire / interview* for conducting voluntary audits per dwelling, in order to know the consumption habits of the occupants of the buildings.

  The participation rate was 71% (40 completed questionnaires from 56 homes) and they have allowed an input of information for designing the improvement measures to be applied in refurbishment. Besides the face to face contact with neighbors is crucial for their involvement in the process and to break the barrier of distrust of new experiences. The presence of the same interlocutors throughout the process is essential.

- *SMART Metering*: Installation of energy consumption monitoring in homes to allow a better understanding (Image 1). On the one hand it gives infromation on the initial consumption, to design a personalized advice over time, and on the other hand, it gives information on the final consumption after the completion of works to quantify the energy savings achieved and assess the impact of the tips given (5).

  After installation of real time consumption meters, users showed changes in attitudes and behaviors related to electricity consumption. The data obtained in certain households (in some, power consumption was already very low for scarce economic resources of the household), showed a higher level of awareness regarding the power consumption of the house and about the consumption of the monitored devices. The people showed curiosity about their own habits and electricity bills analysis, and about how to change the behaviors to reduce the consumption. In fact, Norway researchers found that by improving the accuracy off electricity bills and providing extra information would encourage consumers to read them more often and with greater understanding, promoting a behavior change (6).

- *Periodic visits* to provide users with the results of the monthly monitoring reports on its energy consumption discretized per appliances or services and on their evolution over time (Image 2). According to the results obtained for a particular month, the user was given a tip according to the report.

Image 1. Interface of the installed monitor.

Image 2. Staff from IVE visiting a user to deliver the consumer report and the associated tips.

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Regular visits facilitate the monitoring of the data obtained in the monitoring and a better understanding of them by the technicians. Information on the evolution of the user during the process is obtained: Changes in habits, attitudes, concerns, etc:. Timely manner project partners or authority from MED programme have made visits to the pilot projects and this has resulted in conviction of the people of the importance of the process.

- *Production of promotional videos* from users testimonials for further web promotion, briefings, events, etc.
- *Holding of Public Events* coinciding with the end of the works with public character in the vicinity of the apartment blocks as formalization of the project completion and to make it visible in the nearest urban environment and monetize their exemplary character.

Regional action

- *Design of training and dissemination materials* as promotional flyers and posters for events developed in the municipalities. For local media radio commercials were dessigned, as well as advertisements in local newspapers and magazines. Along with this material, presentations that will be taught in public briefings are developed. Voluntary audits were offered to the residents of the town, so certificate of participation is developed to give participants. Products that decrease energy consumption in the home are showed to voluntary audits attendees (timers, low energy lighting, etc..).
- *Formal agreements with municipalities* to develop the awareness campaign on energy saving in households in the village.
- *Holding meetings* with council staff and other representatives in order to coordinate the activities of the awareness campaign to be developed in the town.
- *Development of briefing sessions* where concepts for energy saving at home in simple way are exposed, with information about how to make it and the benefits. It is served together with a workshop where doubts are resolved and energy-saving elements are exposed (timers, low energy lighting, etc..)
- *An Info day organization* including an information stand in a conspicuous place in the municipality where audits will be made, where questions about energy saving issues will be addressed. If possible this stand will feature local business products linked to the energy improvement and energy savings at homes.

Infodays were held in two municipalities of Valencia region, Paterna and Pobla de Vallbona (Image 3 and 4). The preparation of these information days requires the direct involvement of members of the local community, preferably from the public authority, as well as other associations as retirees, housewives, etc ...

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Image 3. Info-day with the intervention of the National Radio


Image 4. Info-day held with an information stand

Actions at the national level

– *Signing of agreements* for the dissemination of related actions and the awareness campaign tools.

  An agreement with WWF(World Wildlife Fund) in this area has been signed in order to create synergies and supports in the dissemination of similar actions.

  Over 40 events with housewives associations and other groups have been held to spread the web tool.

– *Creation, development and maintenance of a online platform* to provide information to citizens about all activities and materials developed during the awareness campaign (Image 5). The information available in the platform is free access, free download and free use.

  The contents of the web platform http://www.five.es/calidadentuvivienda/ are crucial in the success of visits.

Image 5. Online Plataform "REHABilita tu vivienda" (Refurbish your house)/Tip sheet on middle investment and personalized report on energy consumption.

– *Preparation of an audit tool* that allows users to check with respect to an established scale, what is their diagnosis on energy consumption in their home and according to the results it also provides some tips addapted to the consumer profile (7).

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The tool also allows users to gather information and generate a database on consumption in households with limited means that can be vey useful for further studies.

– *Holding dissemination workshops*, preferably with the support of public authorities, neighborhood associations, consumer associations, etc.. and spread them through the media, dissminating the content and the web platform.

CONCLUSIONS

ELIH-MED Experience indicates that feedback information on energy consumption promotes energy savings in households. To promote energy saving when a building retrofit is undertaken, an awareness campaign should be designed to fix and obtain the fulfillment of two fundamental objectives: present information and feedback as adequately and increase and maintain the users' motivation.

For high effectiveness of public awareness tools, after the experience of ELIH MED, the following considerations must be taken into account:

At the local level, the provision of information on an ongoing basis is essential to and this information need to be adapted to the language of the recipient. The information provided should involve feedback to capture consumer attention and should link specific actions to their effects. The awareness campaign on this scale causes users to begin reading their bills more frequently and with more understanding and to improve their behavior related to the energy consumption. Actions to involved them in the renovation process should exist, so they feel part of it. Moreover, the developed tools should be linked to the capabilities of users (in the case presented, the internet access was poor). Finally, and of great importance, to establish a close and trusting relationship with users is needed, in order for them to be able to express their questions and concerns freely.

At regional level, participation and involvement of other stakeholders is crucial: municipalities, local businesses, etc. To use local and national media for visibility and for promoting this information causes high-impact.

Nationally, the real testimonials from users generate empathy in other users who visit the online platform. Besides this type of action is fed back as neighbors that appear are more involved and responsive in their processes because they see their experience visible. A key for hearing is to provide specific and useful tools (self-audit, advice sheets, etc.).

A plan to reduce CO2 emissions aimed at housing retrofit, needs the active participation of its occupants to achieve its objectives. Many studies have found that changing user habits can produce significant energy reductions, ranging between 25% and 50%.

The experience carried out and presented in this paper suggests that efforts to encourage households to change behavior related to their energy consumption should be an essential component of any carbon reduction strategy. Over 70% of households which will be inhabited in 2050 have already been built, so it will be essential to implement such initiatives.

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Does the design of the built environment have a role in motivating and increasing participation in creating sustainable communities and living sustainable lifestyles?

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Abstract: *Creating sustainable, low carbon communities requires the active participation of individuals and an understanding of what motivates individuals could help increase participating in sustainable developments. This paper reports on an ongoing study of a) motivations for participating in sustainable communities and adopting sustainable lifestyles, and b) contributions that the built environment can make in motivating and increasing participation.*

The initial findings from 29 in-depth interviews suggest that the individuals instrumental in creating sustainable communities are motivated by an environmental imperative, while individuals that join existing communities are as much if not more attracted to the community aspects rather than the environmental benefits. The built environment's contribution to motivating and increasing participation was found to be currently limited. However, there is potential to better exploit the motivational influence of sustainable high quality buildings and external facilities, as well as the less tangible characteristics that contribute to creating a community identity.

Sustainability, lifestyle, community, motivation, built environment

Introduction

Progress towards reducing carbon emissions has been slow and the overall target for a 20% reduction of carbon emissions below 1990 levels in the EU as set out by the European Energy Efficiency Action Plan16 is highly unlikely to be achieved [1]. However, the EU domestic sector is on track to achieve a 20% reduction by 2020 and is believed to provide the most cost-effective way to achieve further reductions of 40% and 60% by 2030 and 2040 respectively [2]. While legislation is addressing carbon reductions in the new build domestic sector, in the UK the majority of the domestic sector is made up of building constructed before the introduction of improved building energy standards, 85% of which will still exist in 2050 [3]. Similar scenarios apply to other member states. Therefore building owners need to take action and reduce the carbon emissions associated with their dwellings.

Furthermore, energy use in buildings represent only one source of carbon emissions and other lifestyle choices, including those relating to transport and consumerism, need to be addressed as well. As with the choices relating to existing living accommodation, at the moment lifestyle choices are within the decision remit of the individual. Creating sustainable and low carbon communities that include low carbon buildings and support a sustainable lifestyle, therefore requires the participation of individuals prepared to embrace change and follow through a transformation process that can be challenging and can last several years.

In relation to the domestic building sector embracing change can involve retrofitting an existing building, or moving to or building a new home. These changes can disrupt living arrangements and, if relocating, disrupt livelihoods and social networks. Upgrading, developing or changing home can be time-consuming and be associated with significant strain and stress. Essential for a successful transition to and adoption of a sustainable lifestyle is a commitment throughout the development processes, followed by the acquisition of new habits and, if joining an existing sustainable community, a commitment to the aims defined by the community.

Research aims and method

While the majority of people do not attempt such major transformations in their lives, some do and their experiences could inform initiatives designed to support such change. Therefore, rather than identifying the barriers to implementation of sustainable lifestyles and built environment solutions, this research investigates the motivations for adopting such solutions. The research also attempts to identify if and if so how the built environment can motivate and support the adoption of more sustainable lifestyles.

Twenty-nine in-depth interviews were undertaken with individuals who had initiated or had joined developments that provide the opportunity to live more sustainably. The developments in this first phase of research were located in the USA (four communities) and Ireland (one community) and included inner-city (two communities) and rural developments (three communities) adopting standard and cohousing models and including between three and 130 parties (individuals or house units). Phase two of this research will be investigating a similar number of developments in the UK plus individuals who have independently initiated major lifestyle change. The interviewees were directed to discuss a) the history of their environmental consciousness development; b) the triggers and motivators for initiating their lifestyle change; and c) the process, chronology and the outcomes of the change. The interviews, lasting typically between 45 minutes and two hours depending on the interviewee's wish to expand on any relevant subject, were kept open to enable interviewees to also discuss marginally linked issues. The interviews were analysed to identify recurring themes and patterns of behaviour, as well as practical technical and socio-economic aspects that affect the ability and motivation to undertake major lifestyle change related to the built environment.

The interviewees: Environmental consciousness and community living as drivers

In all communities studied, the initiators of the development initiative, whether individuals or as a group, fall in the category described by Rogers [4] as "innovators" within Rogers' "Diffusion of innovation" conceptualisation of how innovation is adopted by populations including in the fields of agricultural, where Rogers began his studies in 1962, public health, marketing and many more. "Innovators" are people who are well connected and informed about general issues and those of specific interest and willing to try untested concepts. The initiators of the sustainable developments studied had well-established environmental concerns before beginning to consider developing a sustainable housing development and investigating practical options. For these individuals environmental concerns were the primarily drivers and most did not experience a specific trigger that initiated their action, but rather formulated a plan of action over several years, even decades. Typically the "innovators'" vision was holistic and included sustainable solutions for the built environment, food production, transport and community building.

The participants other than the initiators, who would be classified by Rogers [4] as "early adopters", could be grouped into three groups. There is no clear division between the first two groups as they differ in level of prioritisation rather than by virtue of having distinctly different interests. The smaller of the two groups stated environmental concerns as the main reason for wanting to live in a sustainable development and community; while for the larger group the wish to live in a community with like-minded individuals was their priority, and the fact that the development had low environmental impact was desirable as opposed to essential. A third minority group was only interested in the community aspects the developments could offer and indeed one interviewee stated their scepticism about global warming. Energy efficiency and low running costs were generally not mentioned as drivers for embarking on sustainable developments, however when asked, most interviewees felt they lived in communities that were more resilient than the average community to changes in future resulting from climate change, peak oil and the potential related social unrest.

For many of the "early adopters" the decision to join a sustainable development project was triggered by a single event, be it a divorce, retirement, illness, first-time personal experience of sustainable living, or a seemingly sudden realisation that their current or expected future lifestyle was simply not "right". Interviewees mentioned trying to move away from a lifestyle characterised by stress that prioritised material goods ahead of time with family and to enjoy social relationships. Interviewees also mentioned a wish to be closer to nature and this applied to the rural developments, which were close to farms and allotments, and also to the urban developments, which had integrated natural elements such as roof gardens and vegetable gardens.

Following the trigger event, the "early adopters" initiated a research for solutions that fitted their needs. The interviewees appeared to follow the pattern observed by Rogers [5] in his early research when he noted that farmers were more receptive if the information about the innovation was presented through personal experiences that gave meaning to the innovation. In a similar way, in their search for potential developments the interviewee seemed to rely on information provided by individuals they knew who could illustrate the concepts and give credence to the plans. Two of the established developments still recruiting new members have a system that welcomes visitors who can experience firsthand living in a sustainable community before committing to joining on a permanent basis.

The built environment: Barriers
The building development process including its complexities, duration and financial commitment proved for some individuals to be an insurmountable barrier to participation. The interviewees of the three developments involving capital investment reported numerous early stage participants who were unable to proceed due to their financial limitations. One such individual now lives outside one of the sustainable development in more affordable accommodation and expressed the intention to undertake an energy retrofit at some stage but to date has not done so. Another interviewee and “innovator” founding member of one of the developments, is in same situation and is now planning a strategy involving a cohousing facility to overcome the financial barrier. This process will however prolong by at least a couple of years the transition period before being able to move into a sustainable home.

The least mainstream community in the US did provide opportunities for very low cost housing that could be self-built, very basic in terms of facilities (communal washing facilities were provided to use for a fee) and small in size. Also one of the cohousing schemes offered participation through renting. Participants tended to conform to the parameters set by the overall development and community, therefore where low cost opportunities were available they were adopted, and where they did not exist potential participants rarely pursued alternatives.

While limited financial support was being offered, participants gained practical, information and moral support from other participants. Most interviewees mentioned the evidence of potential support was a motivator to proceed with the development or change of home and lifestyle. It is worth noting that many of the interviewees did not employ sustainable design consultants and relied on personal research and peer support to inform their design and construction. The reasons for this vary, but it would seem that more accessible and affordable support would help address some of the practical barriers experienced.

While the development process can represent a barrier, the completed buildings and associated public spaces can represent a benefit of the new development and life and in certain cases act as motivators to undertake the lifestyle change.

The built environment: Benefits that are not generally motivators
Sustainable and energy efficient buildings can provide low running costs, however for individuals who can afford to build a new home or retrofit their existing home the energy savings are a recognised benefit but do not act as a motivator to undertake the building work. Conversely the individuals who would be attracted to reduced building operating costs do not generally have the capital to develop or upgrade a building. Only one of the interviewees mentioned the fact that they were now in a much larger home than before and their heating costs were a fraction of what they used to be. There is currently little evidence that low energy buildings attract a premium by virtue of their low running costs and the interviewees’ lack of comment on the matter seems to confirm this.

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The built environment: Benefits that could act as motivators

Several interviewees in Ireland mentioned the benefits of warm and dry houses. In comparison to existing building stock, which is typically un-insulated masonry, super-insulated new homes that might need heating three months instead of more than six months per year and provide a healthy and dry indoor environment appear very desirable. As one of the interviewees said “I did want to live in a warm draft-free house. I though well why wouldn’t you, it makes sense.” Triple glazed homes were reported as creating quiet and calm environments. Where natural materials were used, interviewees remarked on the fact that these contributed to a healthier environment.

These results suggest that certain qualities (light, thermal comfort, noise) typically associated with mainstream high quality housing models but also typical of sustainably homes, could act as motivators for individuals wanting to build or move into such buildings. However, several individuals who discussed these qualities had not thought about them before moving, so while these qualities were recognised as a benefit, they had not acted as motivators to move. This suggests these qualities have to be experienced firsthand to be fully appreciated and be able to act as motivators for action. Providing people with an opportunity to experience such environments firsthand could help motivate people to change.

Motivators: The built environment as a framework for high quality and resilient lifestyle

The main motivator for embarking on a lifestyle change that included living in a new development was the perception that this would provide an improved lifestyle within a community of like-minded people. This meant different things for different individuals and settings but some common views exist. The key characteristics named by the interviewees to describe their new lifestyle included: being part of a community, benefitting from a support network, the ability to undertake more meaningful activities, and living in an environment that suited their needs and ideals. Additional elements that contributed to a high quality lifestyle included: reduced commuting, facilities and activities for children, access to healthy food, and living in a context that supported physical activity.

The built environment can support and in certain instances is critical to achieving some of these lifestyle characteristics. Interviewees with children were attracted to developments where the buildings and external spaces were configured to create a safe and stimulating environment for children to play unsupervised. This provides children with more independence, more friends and more interesting experiences, as well as freeing up parents to undertake other activities. Equally the emphasis put on the integration of green leisure spaces and spaces for food growing within the developments was seen as improving the quality of life and health and acted as a draw. Developments that integrated facilities for employment helped reduce commuting, and facilities for safe cycle storage and initiatives and facilities for car clubs supported the use of alternative means of transport.

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A few individuals were drawn to participate in their development by its perceived resilience to the pressures they foresaw resulting from climate change and peak oil. Very low energy and in certain cases off-grid buildings with food growing facilities represented a more secure future.

However, some key motivators, such as being part of a community, benefitting from a support network, the ability to undertake more meaningful activities, are not clearly connected to the nature of the built environment. Perhaps the symbolic value of a clear identity that can be associated with a building complex helps to create a sense of community. Perhaps a building complex that enables individuals to grow their own food, help one another by sharing chores, and reduces their environmental footprint can contribute to a feeling of undertaking more meaningful activities. Perhaps the process of developing a building project as a group also contributes to the building of a community. What is clear is that the link between the key motivators and the built environment is indirect and will need further investigation.

Conclusion

This ongoing research investigates the role of the built environment in motivating and increasing participation in creating sustainable communities and living sustainable lifestyles. While overall the research suggests the built environment's role is limited in these respects, there are some aspects of a sustainable built environment that motivate participation; in particular the quality of internal and external spaces and facilities provided, and the more intangible characteristics that help create a community.

Key barriers to creating sustainable communities and living sustainable lifestyles can be the capital cost and time required for the transition process. Considering that for the "innovators" the process from formulating the aim of changing their lifestyle and living in sustainable development to the realisation of their aim could be as long as a decade, it is critical to develop methods to accelerate participation and create a critical mass of individuals prepared to invest, both time and money, to live more sustainable lifestyles.

While the built environment is a minor motivator for adopting sustainable lifestyles it is worthwhile focussing on the benefits of sustainable built environments that are attractive to potential participants. The quality of internal spaces (light, thermal comfort, noise attenuation) and quality of and integration of green spaces and safe spaces for children are motivators for moving to developments. These are characteristics that are also associated with high end market properties and the challenge is to educate the public that these qualities can be achieved in buildings with very low environmental impact. The industry needs to raise awareness of these benefits and ensure that low energy and low carbon becomes equivalent to high quality. Such information needs to be made available through popular media to reach a wide range of people who do not have access to specialist information sources. It is perhaps time for a television soap situated in a sustainable community depicting a high quality environment inhabited by ordinary individuals who just happen to have specific priorities and interests but are otherwise "normal".

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For many of the interviewees joining a community was a key motivator. The ways the built environment can act as the framework for a community needs to be better understood. How environments can encourage interaction is well known, but the contribution of buildings to creating a community identify and a feeling of shared purpose needs more research. Joining a community with ethical and lifestyle goals similar to one's own is a strong motivator, whether the built environment can express these values to attract similar-minded people and whether this can in practice act as a motivator should be investigated.

The fact that participants in sustainable community developments are not necessarily interested in environmental activism is a sign of the potential for mainstreaming the sustainable community model, especially if the above-mentioned advantages are adequately advertised. A change in values may not be necessary to live more sustainably by growing one's food, become involved in community activities or shared facilities, and enhance the local environment for the benefit of humans and other species. However, some aspects of sustainable living are more difficult to sell; only a minority of individuals will opt to retrofit their house to improve energy performance instead of extending the house to increase usable floor area. Overcoming these preconceptions, not selling the benefits of high quality housing, safe play areas, green spaces and so on, is perhaps where the real challenge lies.

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Session 134:

What saving potential do passive measures have?

Chairperson:

Solé, Josep
European Sustainability and Technical Manager at URSA Insulation. Barcelona, Spain

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Importance of orientation in building energy-savings

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Abstract: *In the design of new buildings, project energy efficiency is nowadays one of the most important parameters on its development. The energy crisis on which we live and the greater social awareness have allowed efficiency be a major factor when we are thinking in a new building solution. This search for efficiency must be supported by studies to quantify these improvements. With this information we can assess which one of the different solutions is the best.*

The building sustainability is closely related to building efficiency. The present analysis shows through a semi-attached house, the importance of building orientation in heating and cooling demands. With this knowledge we can choose the orientation with low energy consumption.

Keywords: Energy efficiency, simulation, orientation, BEM, energy-saving, sustainability.

1 INTRODUCTION

Generally building orientation has been decided by the influence of views, prevailing winds, housing layouts, site topography, nearby buildings, etc. Other times urban planning depends on older planning, road existing layout, which purpose is ease of execution, road camber, etc. Unfortunately sometimes the design of buildings doesn't consider the energy-savings of this energy efficient factor (orientation). Take into account prevailing winds to design building layout to make cross ventilation, or rotate the building to have solar gains in winter are restricted by above reasons.

Nowadays the new simulation programs shows easily and quickly the influence of these factors in building energy demands. Today are real design tools that after comparative analysis show us energy behaviors that aren't a priory obvious.

The orientation of house layout affects its energy demand, because varies how much influence has other factors like incident radiation, wind exposure, etc. For example a window opening west-facing will have more solar gains in the afternoon, and this one will be greater in summer than in winter because it has more hours of sun exposure. The same window opening south-facing will have more solar gains in winter than in summer due to solar zenith angle although solar radiation intensity be greater in summer than in winter. Relative to wind, façades with openings facing prevailing winds have more infiltrations due to high wind pressure.

This paper analyzes one type of house, in particular a semi-attached house, because it is fairly generalized in the surroundings of Spain capitals. To give more variability, three different houses was made with different window opening percentages. The increase in window openings is proportional to the initial opening. The different percentages simulated are 10%, 15% and 20% (this percentage refers to the total area of the façade). In case 1, 10% of the façade are window openings; in case 2, 15%; and in case 3, 20%. In each simulation, housing has been rotated 15 degrees which has allowed knowing the optimal orientation and the different amount of energy between the worst and the best orientations. With this information we can determine the energy-savings that we can obtain if the building is correctly oriented.

2 GENERAL CONSIDERATIONS

The following describes each one of the aspects have been taken into account when performing both simulations and analysis.

2.1. SIMULATION PROGRAMS

For the development of building energy model (BEM), OpenStudio 1.3.0 software has been used. This program has been developed by NREL (National Renewable Energy Laboratory). It is a graphical interface that allows users to create the building envelope taking into account all different input parameters that define it. Moreover this software has the possibility to analyze the simulation results graphically. The calculation engine of this tool is EnergyPlus software.

After the model was developed, the simulations have been made with EnergyPlus software 8.1.009. This software is a whole building energy simulation program use to model energy and water use in building. "Enable building professionals to optimize the building design to use less energy and water." It has been developed by U. S. Department of Energy (DOE). "EnergyPlus models heating, cooling, lighting, ventilation, other energy flows, and water use." Enable to obtain information relative to building behavior (indoor space temperature, loads, heating and cooling demands, etc.). It has passed the verification and validation test of IEA BESTEST procedure (developed in conjunction with the International Energy Agency (IEA) Solar Heating and Cooling Programme (SHC)).

2.2. WEATHER DATA

The choice of weather database to do the simulations is a very important aspect (Ramos. G, Fernández C., 2013). For this analysis, Meteonorm 7 database was used. This software generates weather files in many different formats using the data of the weather stations or interpolated them if don't have a particular location. For generating results, the program has different options to establish the typical year that be more closely to the real year. About temperatures we can choose between different settings 1961-1990, 2000-2009, or future

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years; and about solar radiation between 1981-1990, 1986-2005, or future years. Solar radiation measurements also can be corrected, add atmospheric turbidity, calculate radiation data on surfaces with different degrees tilt angle, etc. The simulations of this analysis use the original values of the weather stations, without any changes, choosing temperatures values between 2000-2009 years and about solar radiation between 1986-2005 years.

One of the reasons for choosing this weather database is that the existing database on EnergyPlus web doesn't have values of wind velocity and wind direction (the values of wind direction are constant – 0 degrees – and wind velocity 6.4 m/s). Meteonorm database has different hourly values for wind. These aspects have a great influence on infiltrations, and thus in heating and cooling consumptions.

2.3. SEMI-ATTACHED HOUSE DESCRIPTION

The chosen semi-attached house has a surface of 460.92 m^2. A "semi" is a house that is joined to another house, so has one sidewall in common with the other house. It has been considered as a whole so all the envelopes are exterior, enhancing the impact of climate and orientation (figure 1 & 2). The envelope is made of facing bricks and has been considered 5 cm of insulation (Expanded Polystyrene - EPS).

These types of houses have a very marked directionality due to the size and position of window openings. There are two façades with great prominence, the main façade (facing the street), and the rear façade (facing the garden). The other two are a sidewall linking with the other house and a very opaque façade. This distribution of window openings makes the influence of orientation be greater than if we had a more uniform distribution.

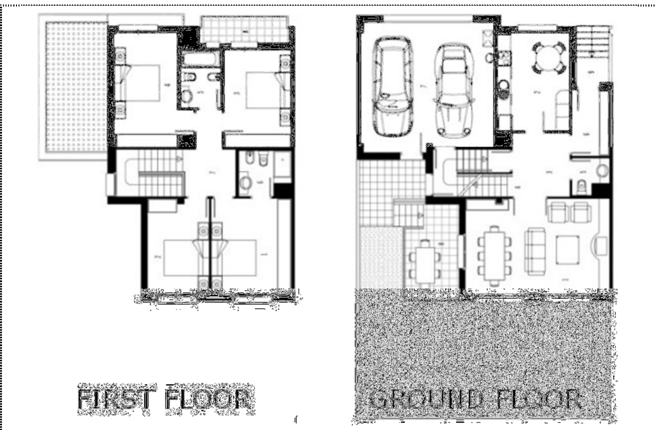

Fig. 1.- *Layout of the semi-attached house under study*

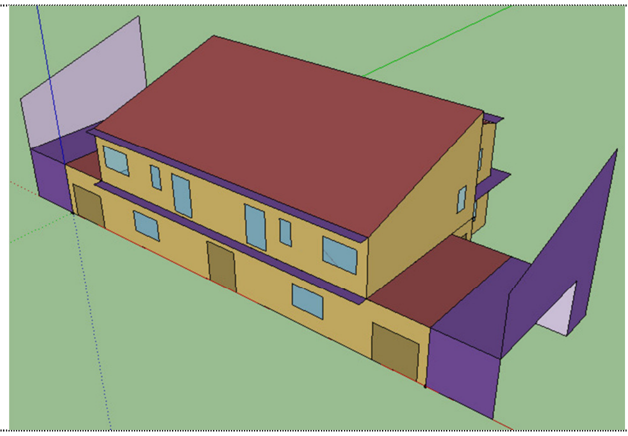

Fig 2.- *Semi-attached house OpenStudio Render*

2.4. SIMULATION PARAMETERS

In the simulation there are many aspects to take into account: heating and cooling set point temperatures, use schedules, people activity levels, internal loads, lights, equipment (TV, computers, fridge, etc.). There are many different criteria to define each one, so it has been decided to choose the normalized residential use profile of the new Spain code CTE-DB-HE

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("Código Técnico de la Edificación, Documento Básico HE – Ahorro de Energía" - September 2013). The following describes each one of these aspects.

Housing occupancy: Weekdays from 0:00h to 7:00h and from 23:00h to 0:00h the occupancy is 100%; from 7:00h to 15:00h, is 25%; and from 15:00h to 23:00h is 50%. On weekends the occupancy is 100%. It has been considered that 12 people live in the houses whose load is 90 W/person.

Equipment: The use of these equipment is 20% from 0:00h to 7:00h, 50% from 7:00h to 23:00h, and 100% from 23:00h to 24:00h. The loads of these equipment are 2.2 W/m^2.

Lights: The use of these lights is 20% from 0:00h to 7:00h, is 50% from 7:00h to 23:00h, and 100% from 23:00h to 24:00h. The loads of these lights are 2.2 W/m^2.

Infiltrations: It is the flow of outdoor air into a building from outside unintentionally. There are mainly due to shutter boxes, windows sealing (window, frame and divider), kitchen and bathrooms vents, cracks in the building envelope, etc. It depends on wind velocity, pressure and depression between the main and the rear façade, building airtightness, etc. It is measured in air changes per hour (ACH). It has been considered the values established in "Condiciones de Aceptación de Procedimientos Alternativos a LIDER y CALENER", these rate is 0,3 ACH for detached houses.

Ventilation: It is intentional introduction of air from the outside into a building. It is further subdivided into natural and mechanical ventilation. The document sets a value of 4 ACH from 0:00h to 8:00h in summer (it supposed that the windows are open), and for all other cases refers to the Spain code CTE-DB-HS3. The rate of ventilation in this case is 0,63 ACH.

Cooling set point temperature: (summer) (from June to September). The set point is 27ºC from 23:00h to 7:00h, and 25ºC from 15:00h to 23:00h. It is supposed that from 7:00h to 15:00h the house is empty and unused, so doesn't have cooling set point. Nowadays due to the actual economic situation, the possibility that these houses be in use are high.

Heating set point temperature: (winter) (from January to May and from October to December). The set point is 17ºC from 23:00h to 7:00h, and 20ºC from 7:00h to 23:00h.

3 METHODOLOGY

The EnergyPlus model generated in OpenStudio take into account all considerations described above. A parametric study has been made with the simulations of the three different energy models (10% window openings, 15%, and 20%), in 52 capitals of Spain, and in 24 different orientations (between 0º and 360º range, in 15º intervals). The simulations have been made with ideal loads that supposed an HVAC (heating, ventilation and air conditioning) performance of 100%. This is a comparative analysis and we are interested in the influence of orientation and not in the behavior of HVAC equipment. This analysis compares the outputs

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of these simulations (3744 cases), particularly the heating and cooling demands in kWh/m^2/year.

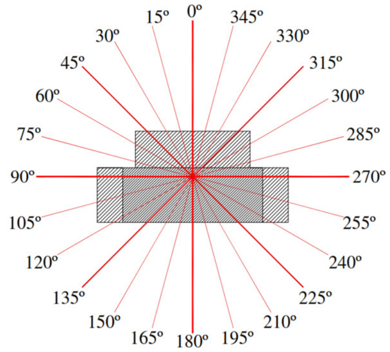

Fig. 3.- Orientation of the building (Each value is North direction)

ORIENTATION	MAIN FACADE	REAR FACADE
0	SOUTH	NORTH
45	SOUTH-WEST	NORTH-EAST
90	WEST	EAST
135	NORTH-WEST	SOUTH-EAST
180	NORTH	SOUTH
225	NORTH-EAST	SOUTH-WEST
270	EAST	WEST
315	SOUTH-EAST	NORTH-WEST
360	SOUTH	NORTH

Fig. 4.- Correlation between degrees of orientations and the orientation of the main and rear façade

Also, a sensitive analysis has been made to view the importance that orientation have in the building energy consumption (Robertson, J., Polly, B., & Collis, J., 2013). Figure 3 explains the meaning of each simulated orientations. Each value is North direction, and the main façade is the largest. Figure 4 shows the correspondence of main and rear façade with orientation. There is a little difference between them, because the main façade has smaller openings than rear façade (60%). The rear façade have the greatest window opening surface of the building.

4 RESULTS ANALYSIS

Figure 5 shows summary graphs of the obtained outputs of simulations. From top to bottom are sorted by latitude the different cities of Spain. High latitudes are on top (Santander, Oviedo …) and low latitudes on bottom (… Tenerife, Gran Canaria). From left to right are sorted by the percentage of energy difference existing with different orientations in 15º intervals (0º left side to 345º right side). For better clarity (due to the size of graphs), cells in deep red represent the orientation of the greater values of heating demand, and in deep blue the cooling demand. Cells in light red and blue represent the values with lower heating and cooling demands respectively.

Figure 6 shows the relation between the orientation in which the maximum and minimum energy demands have been produced, and the number of corresponding cities. From the center of the circle to the edge is the number of cities (0-52). Each of radii of the circle represents the North direction angle. The selected color code to distinguish each one of the demands is the same than in figure above.

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10% openings | 15% openings | 20% openings

Fig. 5.- *Perceptual difference in energy consumption with different orientations*

As can be observed in the various graphs, in all cases when the main façade is South-West facing (between 60º to 75º) the maximum heating demands occur, and if it is North-East facing (between 255º to 270º) occurs the maximum cooling demand. The optimal orientation for this kind of building, with minimum heating and cooling demands, are when the main façade is North facing (between 165º to 195º) (remember that the rear façade has more opening windows surface than the other ones). With 20% of window surface, the optimal orientation for cooling is 0º. The reason of this change is that as we increase the size of windows, the rear façade (with the biggest windows) need more cooling to reach the assigned set point. However the difference with 165º to 195º is really low.

The reduction in heating demand occurs when façade with big openings is South facing (rear façade with 180º). In winter and in this latitude, the sun is low in the sky and the building has more solar gains. In summer, the optimal orientation matches with winter orientation because in these months the sun is high in the sky and has lower cooling demands. Keep in mind that the simulated building has cantilever slabs in the main and rear façade, so in summer these slabs are like sunscreens that project shades on the façade and thus reduces the cooling demand.

Nonetheless the difference between the maximum and minimum energy demand in kWh/m^2/year is very low. Statistically, for 10% opening case the second quartile is 2.57 kWh/m^2/year; for 15% opening case is 3.59 kWh/m^2/year; and for 20% opening case is 4.71 kWh/m^2/year. Its sensitive coefficients are 0.123 for cooling and 0.0175 for heating in 10% opening case; 0.128 for cooling and 0.026 for heating in 15% opening case; and 0.145 for cooling and 0.0368 for heating in 20% opening case. This indicates that although the orientation it is a factor to consider if energy saving is the objective, its influence on the total

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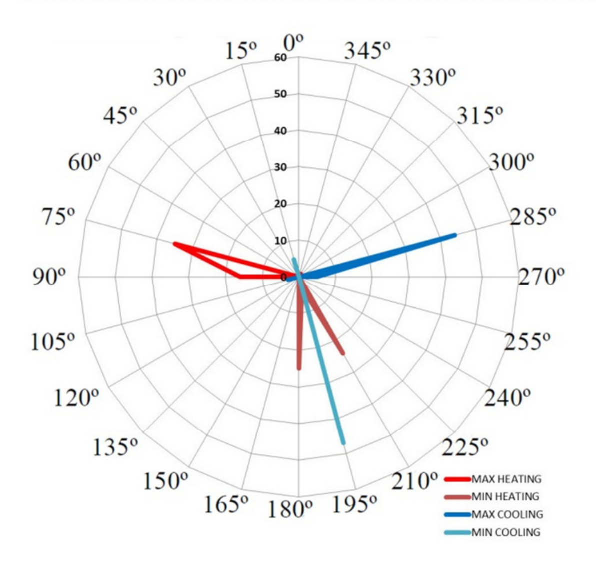
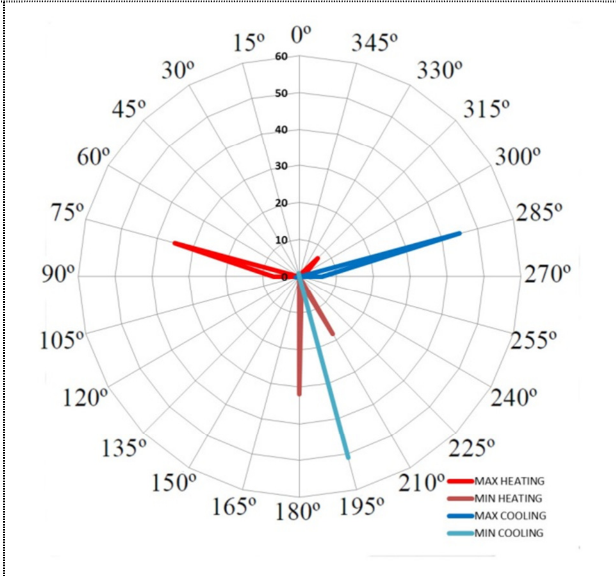
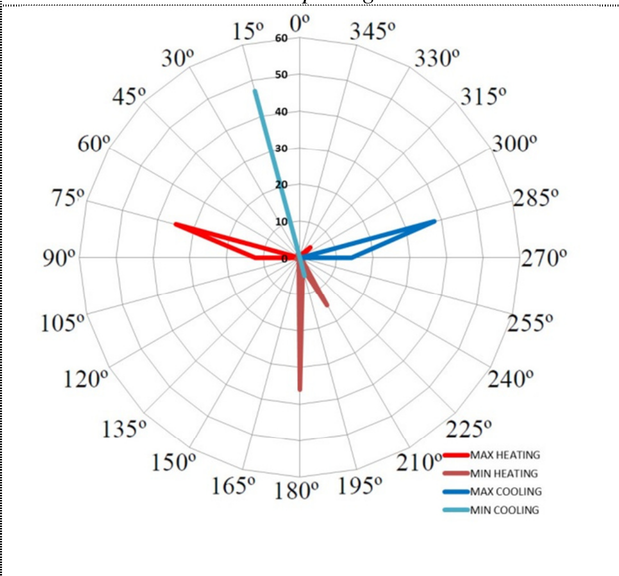
energy demand is not as important as other factors (infiltrations, thermal inertia, insulations, etc.)



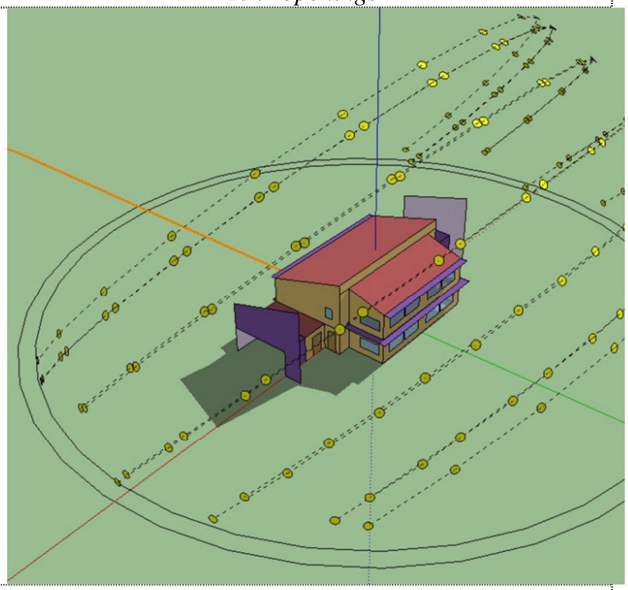
10% openings



15% openings



20% openings



Render with shadows of the rear façade (180º - July)

***Fig. 6**.- Relation between different orientations*

Is noteworthy that for Spanish latitudes there is no difference in the optimal orientation when changes the location. For this particular case all the optimal orientations are the same.

5 CONCLUSIONS

After analyzing the results it can be concluded that for the case of semi-attached houses, with high sizes of windows in the main and rear façade, the optimal orientation to obtain lower heating and cooling demands occurs when the façade with bigger windows is South facing (obviously with sunscreens for summer).

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This optimal orientation is fulfilled in all Spanish territory. The reason is the low latitude variability in Iberian Peninsula. For this reason, after this analysis it has been simulated the same cases in the 28 capitals of the European member countries, with the same orientations and sizes of window openings (2016 simulations). The obtained results do not differ significantly from the ones obtained in Spain simulations. Although the optimal orientation of the cities with high latitudes is displaced to 195º-210º (façade with bigger windows is South-West facing). The orientations with maximum demand values are similar to Spain case, but with higher latitudes than 53º North there is a high dispersion of results.

Finally, although the building orientation is not a determining factor in the design of buildings (due to the low energy savings), take into account these orientations allow us to have low energy consumptions to reach thermal comfort.

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Re-considering thermal insulation under Mediterranean conditions

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Abstract: *In order to achieve the net-zero energy goal in buildings, several construction techniques, high efficiency Heating, Ventilation and Air-Conditioning (HVAC) systems and state of the art Renewable Energy Systems (RES), can be used. The factor that influences the effective combination of the adopted techniques is the minimization of the buildings' energy demand. Increased thermal insulation thickness will result to the selection of HVAC systems with low output power. In that sense, the final energy consumption will be counterbalanced by the lower energy that must be produced from RES. In this study, the optimum thermal insulation position is evaluated for a given typology of a representative residential net-zero energy building located in the Mediterranean region. The integrated evaluation was carried out by performing an extensive life cycle analysis of the environmental, energy, economic and thermal comfort performance of several thermal insulation configurations implemented.*

Thermal insulation, Thermal comfort, Life cycle assessment, Mediterranean region

Introduction

The environmental impact of buildings includes both their energy consumption during their lifetime and the production of construction and demolition waste. Thickness and the position of insulating materials in opaque building elements are major factors that affect both the energy performance and the overall environmental impact of a building. Together with the thermal mass of the building elements and their other thermo-physical properties (like absorptivity, emissivity and thermal diffusivity) those building construction features affect, beyond the thermal transmission of the building, the prevailing mean radiant temperature indoors which, in turn, is a significant component of the thermal comfort's perception. Thus, they do not only play a most significant role for the energy consumption required to maintain thermal comfort conditions inside a building, but they directly affect the perception of thermal comfort, which is usually not considered by studies aiming at the optimization of the selection of thermal insulation solutions for various' buildings elements [Asan, 2000; Balaras, 1996; Bolatturk, 2008; Ozel et al., 2007]. This is even more critical in the case of refurbishment and energy upgrading of existing buildings, where improving thermal comfort is a main desideratum. Djuric et al. analyzed how the insulation thickness of the building's envelope, the supply-water temperature and the heat exchange area of the radiators influence the thermal comfort, the energy consumption and the investment cost.

Methodology adopted

The present study focuses on determining the optimal position of thermal insulation materials. The integrated evaluation of the optimal position of the insulation materials was carried out

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by performing an extensive life cycle analysis of the environmental, energy, economic and thermal comfort performance of equivalent thermal insulation configurations implemented in all four external building elements for a given typology of a representative residential building located in the Mediterranean region. The European building's insulation market is dominated by three insulation materials' families: Expanded polystyrene (EPS), extruded polystyrene (XPS) and stone wool (SW). In order to conduct this study a multi -family residential apartment building was chosen [Papadopoulos et al., 2008]. It is a three-storey building with two apartments per floor, a total heated area of 684 m^2, a he cooled area of 540 m^2 and a window to wall ratio of 17%. It is a fairly representative for the urban multi-building stock in the Mediterranean area (Greece, Cyprus, Italy, etc) [Theodoridou et al., 2011].

In total, twenty three different thermal insulation configurations of several building elements with different positioning of the insulating layer were evaluated for four Greek cities each representing one of the four different climatic zones of Greece. It has to be underlined that those Greek cities display climatic features similar to major cities in the Mediterranean region, as presented in Figure 1. The thermal insulation configurations considered satisfy the energy regulation limits imposed by the Greek Regulation on the Energy Efficiency of Buildings which resulted from the harmonization of the initial Energy Performance of Buildings Directive (2002/91/EC) and achieve respective thermal resistance and overall heat transfer coefficient values. Regarding the vertical building elements, twelve conventional insulation configurations, eight with the installation of an External Thermal Insulation Composite System (ETICS) and three with internal insulation are considered for all the climatic zones; they are presented in Figure 2.

Zone	Greek cities	European cities in the Mediterranean region		Climate features
A	Rhodes	Larnaca	Palermo	Humid subtropical. Mild with no dry season, hot summer. Warm - Humid. Humid Subtropical (Warm Summer)
B	Athens	Izmir	Brindisi	Humid subtropical. Mild with no dry season, hot summer. Warm - Humid. Humid Subtropical (Warm Summer)
C	Thessaloniki	Madrid	Istanbul	Humid subtropical. Mild with no dry season. Hot summer. Warm. Marine. Dry Summer Subtropical (Mediterranean)
D	Florina	Milan	Torino	Humid subtropical. Mild with no dry season, hot summer. Mixed. Humid. Humid Subtropical/Humid Continental (Warm Summer)

Figure 1. Cities with similar climate features in the Mediterranean region

The building features a central heating system, fed by an oil-fired boiler with an efficiency of 0.90. In the rooms the heat is distributed by hydronic radiators. Thermostatic control is provided in each apartment, with set temperatures of 20°C during daytime and a night setback at 15°C. Typical ventilation and infiltration values were considered, of 1.0 air change per hour for the main rooms of 2 for the kitchen and of 4 for the sanitary rooms. With respect to cooling, the living room and the two bedrooms of each apartment are equipped with split unit type room air-conditioners, having a seasonal energy efficiency rating (SEER) of 3. During the cooling period the RACs' thermostats are at set temperatures of 26°C. The main assessment factors evaluated in this study are primary energy consumption, environmental impact, financial cost and thermal comfort. The life cycle stages taken into consideration consist of the construction phase (which includes the production, transportation and installation of the materials), the building's operation, the dismantling of the building and the

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end-of-life management of the resulting demolition waste. Since no reliable statistical data on the life span of buildings are available, the conventional life span of 50 years is assumed [Famuyibo et. al, 2013]. The building at the end of its service life is considered to be deconstructed and the resulting wastes are transferred to proper recycling facilities and landfill sites. The environmental impact assessment is based on the Life Cycle Analysis (LCA) methodology. In this study, the environmental impacts categories that are thoroughly examined are: Climate Change, Acidification, Eutrofication and Photochemical Oxidation. Every category is characterised by certain emissions (such as CO_2 equivalent, SO_2 equivalent, PO_4 equivalent, C_2H_4 equivalent respectively) that stem from specific procedures within the life cycle of a building. At the environmental impact assessment phase the indicators derived from CML 2 baseline 2000 method were used. All the necessary data for building materials at the construction phase were acquired from results published [Anastaselos et al., 2009; Hegger et al., 2006]. For the output data, namely emissions from production, transportation and installation, the SimaPro LCA software was used, which is a life-cycle analysis model with the embodied EcoInvent LCA database and cost–emission analysis system [Frischknecht et al., 2005]. Finally, for the dismantling and end of life management phase the integrated building energy, environmental and economic assessment tool, namely ib3at© was used [Anastaselos et al., 2011].

For these phases, all the necessary input data were taken from previous studies [Anastaselos et al., 2011]. For the operation phase, all the simulative calculations were carried out using the Energy Plus simulation software. Thermal bridges have been calculated according to ISO 14683:2007 [ISO, 2007]. The economic performance of the insulation configurations is determined with the Life Cycle Costing (LCC) approach. The LCC approach includes the purchase and all associated costs (delivery, installation, etc.), the operating costs, including energy, maintenance, etc. and the end of life costs, such as decommissioning and removal. PMV and PPD were the indexes used to assess the thermal comfort conditions in the present study. For the evaluation procedure the ib3at© tool was used, as it is an integrated building energy, environmental and economic assessment tool, which can also be used separately in order to optimize the materials and systems used in the various stages of a building's life time. The tool considers three main assessment factors; primary energy consumption, the environmental impact and the financial cost; each and every factor is analytically assessed during the four distinct stages of a building's life cycle. The calculation of the aforementioned factors takes place using analytical algorithms.

Results and discussion

The application of the methodology led to the calculation of the overall ranking and the determination of the single optimal solution for every climatic zone. Solutions 20 and 18 (ETICS with EPS on walls, EPS externally on the floors and XPS with inverted roof technique and externally on the roofs respectively) are the ones presenting the lowest final energy consumption for both heating and cooling and PPD index. In general, solutions with external insulation on the vertical building elements are performing better both for heating and cooling conditions. Regarding the overall performance of the various insulation materials

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that are used in ETICS, Solutions 13, 15 and 17 (SW, EPS, XPS respectively) have to be compared as they only differ in the type of the insulation material used in the vertical building elements (load bearing walls of armed concrete and non load bearing brick walls). The results indicate that EPS is the preferable material to be used in ETICS, as it has from 0.28 to 0.46% (from the warmer to the colder climatic zone) and 0.47 to 0.63% lower life cycle primary energy consumption compared to XPS and SW respectively. The differences are admittedly small, expressing a tendency rather than an absolute value.

A/A	Brick Walls	Concrete Bearing Walls	Floors	Roofs
1	SW (MID)	XPS (OUT)	XPS (IN)	XPS (OUT)
2	XPS (MID)	XPS (OUT)	XPS (IN)	XPS (OUT)
3	EPS (MID)	XPS (OUT)	XPS (IN)	XPS (OUT)
4	SW (MID)	EPS (OUT)	XPS (IN)	XPS (OUT)
5	SW (MID)	XPS (OUT)	EPS (IN)	XPS (OUT)
6	SW (MID)	XPS (OUT)	SW (IN)	XPS (OUT)
7	SW (MID)	XPS (OUT)	XPS (IN)	EPS (OUT)
8	SW (MID)	XPS (OUT)	XPS (IN)	SW (OUT)
9	SW (MID)	XPS (OUT)	XPS (IN)	INVERTED (XPS)
10	SW (MID)	XPS (OUT)	XPS (IN)	INVERTED (XPS)
11	SW (MID)	XPS (OUT)	EPS (IN)	INVERTED (XPS)
12	EPS (MID)	XPS (OUT)	EPS (IN)	INVERTED (XPS)
13	ETICS (SW)	ETICS (SW)	XPS (IN)	XPS (OUT)
14	ETICS (XPS)	ETICS (XPS)	XPS (IN)	XPS (OUT)
15	ETICS (EPS)	ETICS (EPS)	XPS (IN)	XPS (OUT)
16	ETICS (SW)	ETICS (SW)	SW (OUT)	XPS (OUT)
17	ETICS (XPS)	ETICS (XPS)	XPS (OUT)	XPS (OUT)
18	ETICS (EPS)	ETICS (EPS)	EPS (OUT)	XPS (OUT)
19	ETICS (XPS)	ETICS (XPS)	XPS (OUT)	INVERTED (XPS)
20	ETICS (EPS)	ETICS (EPS)	EPS (OUT)	INVERTED (XPS)
21	INTERNAL (SW)	INTERNAL (SW)	EPS (IN)	EPS (IN)
22	INTERNAL (EPS)	INTERNAL (EPS)	EPS (IN)	EPS (IN)
23	INTERNAL (SW)	INTERNAL (SW)	EPS (OUT)	INVERTED (XPS)

Figure 2. Thermal insulation configurations under study

The results of the environmental impact assessment evaluation indicate that of the twenty three solutions, Solutions 20 and 18 are, again, the ones performing better, followed by solutions 9-11. The latter are using a combination mainly of SW, which is environmentally more benign than EPS during the construction and end of life management phase. The difference is more intense in the warmer climatic zone A, where due to the increased cooling demand more electricity is required to drive the cooling equipment and hence higher pollutants' emissions are occurring. Finally, regarding the overall rating, the two best solutions, 20 and 18, do not differ substantially in their ranking points. They are using the same positioning of the insulation layer and only the insulation material differs.

For the internal insulation solutions the results vary: Solution 23 (SW with gypsum board on the walls, EPS on floors and XPS on the inverted roof), can be easily implemented for the energy upgrade of existing buildings. It is the best internal thermal insulation solution for all climatic zones. It achieves an overall good final energy performance for heating and cooling aggregated. However, it has a rather poor performance, as it ranks in the 16th, 13th, 20th and 18th place respectively, when considered on the base of the primary energy consumption. This is due to the fact that the internal insulation has a slightly higher energy consumption for cooling (which was also observed in the other two internal insulation configurations). The electricity used to cover the cooling demand is linked to high emissions (particular SO_2) due to the use of lignite fired power plants and, hence, to a poor environmental performance.

A quite interesting remark that is concluded from the interpretation of the results is the small relative reduction of the PPD with respect to the increase of the thickness and the resulting reduction of the U-value of the building elements. In general, the results regarding thermal comfort reveal marginal differences, but this was expected since on the one hand, any insulation solution does have an important impact on comfort and, on the other, all configurations of the building are conditioned by the same heating and cooling systems at the same thermostatic set-points, while the differences on the buildings elements U-values were negligible and in their thermal mass limited (essentially only the floor and roof vary which are represent together 40% of the total building envelope's area). That is why even a 2% difference can be assessed as not unimportant.

Conclusions

Aim of this study was to evaluate the impact of the thermal insulation's position under Mediterranean conditions, in a most comprehensive way. The methodology was applied for the integrated evaluation of twenty three equivalent thermal insulation solutions in various Mediterranean climatic conditions. The type, thickness and positioning of the most common insulation materials was found to clearly affect the final energy consumption, the overall environmental impact, the life cycle cost and the prevailing indoor thermal comfort conditions of a building.

As the results indicate, the implementation of external insulation with the use of expanded polystyrene as an insulation material for the external walls and floors (as part of an external thermal insulation composite system) in collaboration with the use of extruded polystyrene to flat roof construction along with the adoption of the inverted roof technique was found to be the optimal solution for all four climatic zones. Overall, external thermal insulation is the better option for residential buildings, although internal one can also be considered as satisfactory, especially in cases where technical or legal reasons make external insulation difficult to implement.

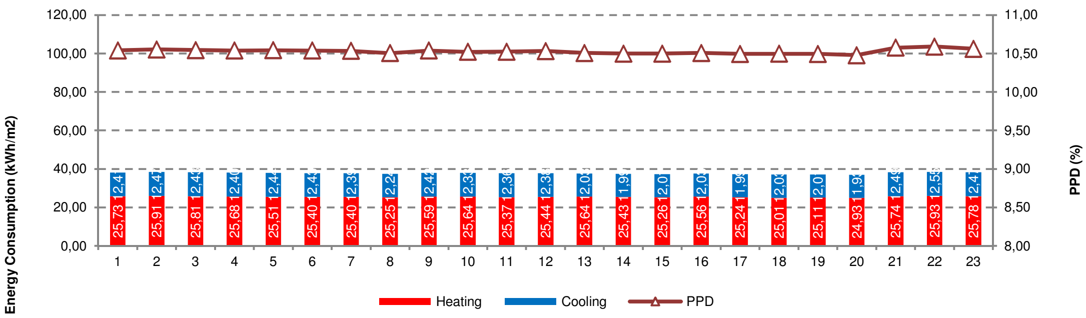

Figure 3. Final energy consumption and PPD of the thermal insulation configurations under study-Zone A

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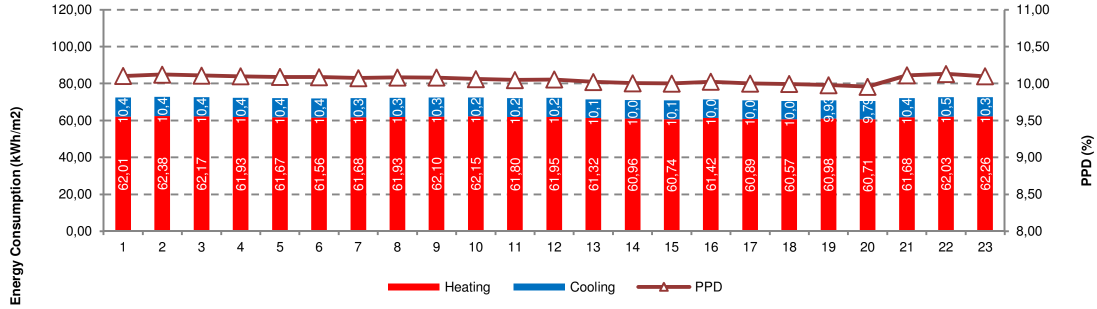

Figure 4. Final energy consumption and PPD of the thermal insulation configurations under study-Zone B

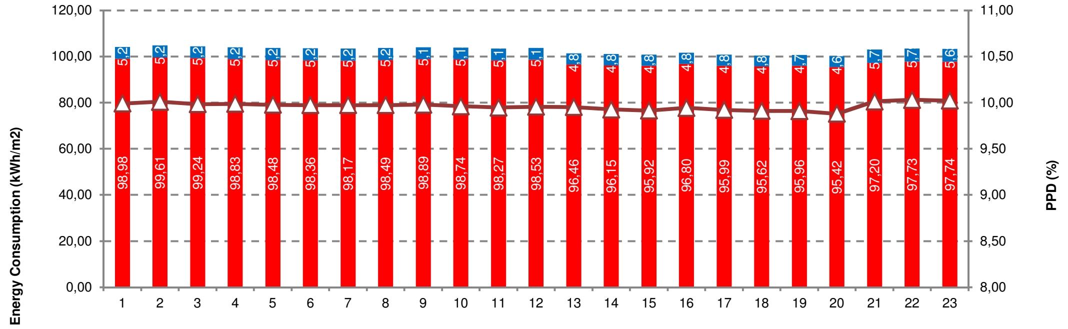

Figure 5. Final energy consumption and PPD of the thermal insulation configurations under study-Zone C

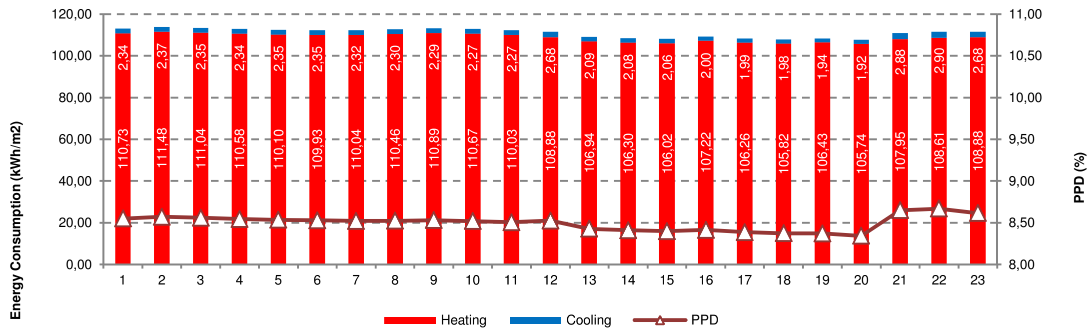

Figure 6. Final energy consumption and PPD of the thermal insulation configurations under study-Zone D

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Net Zero Energy Through Passive Downdraft Ventilation: The Design & Operation of the Conrad N. Hilton Foundation

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Abstract: *The new campus for the Conrad N. Hilton foundation is designed to establish a regional precedent for environmental stewardship, with the goal of being a net zero energy institute. The first completed phase of the campus is a 2,044 m² office building with an indoor environment that balances the needs for excellent indoor air quality, daylight and energy usage through an innovative new passive downdraft ventilation system that is inspired by ancient designs. Passive downdraft has the potential to significantly reduce building energy and enhance air quality (through significantly increased outside air rates (P. Wargocki et al, 2000) in many building types and, especially, in mild climates like coastal California. This paper reviews the techniques of enhanced natural ventilation through the design of the passive downdraft and the performance of the facility as a net zero building after occupancy through the measurement and verification process.*

Keywords: passive downdraft, net zero energy, natural ventilation, verification

Fig. 1: Overall view of Conrad N. Hilton Foundation at night.

1. INTRODUCTION

This paper provides a case study for the Conrad N. Hilton Foundation project, located in Agoura Hills, CA. The 2,044 m² office building, completed in 2012, had a goal of achieving net zero energy use. As part of the strategy for achieving that goal, the project sought to achieve energy savings of at least 50% each in HVAC and lighting systems to limit the amount of renewable energy that would need to be generated on-site. This paper explores the history of passive downdraft systems, how the concept inspired the HVAC system and how it was implemented to achieve significant energy savings. It also describes how the architectural response to the passive downdraft system brought additional natural light into the building by using that space as an architectural ventilation exhaust pathway. In addition, there is a review of the process for showing net zero performance through post occupancy measurement and verification.

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2. HISTORY OF PASSIVE DOWNDRAFT

A wind-catcher is an ancient architectural feature used to promote passive ventilation primarily to cool buildings. Its use dates back centuries, and its effectiveness has led to its continual use as a cooling device in middle-eastern architecture. The ancient Persians' understanding of wind behavior was an important survival tool. They predicted the rare seasons of rain that were dictated by wind movement. They learned to protect themselves from the warm winds that dried their bodies of valuable and scarce water. Through a conscientious trial-and-error process, they understood the physical behavior of wind—buoyancy, convection, evaporative cooling—and were able to harness it to adapt to the harsh climate of the desert. The design of wind-catchers can vary greatly based on the climatic conditions of their regions. The two main types are unidirectional—Malqaf, used widely in Egypt—and multi directional—Bâdgir, used widely in ancient Persia.

The Malqaf consists mainly of a scoop, which rises above the roof of a building to catch the prevailing cooler, stronger winds. The force of the prevailing wind drives the cooler air down the chimney and into the occupied spaces below. This pressure forces the air out through openings at the top of a central hall. Comfort is achieved by promoting air flow over the body and by removing excess heat that is generated by occupants. The Bâdgir is a shaft that rises three meters above the building, with openings on all four sides to catch breezes from any direction. It was developed in Iran around 900 AD. Designed to work both as an intake and as an exhaust, a Bâdgir's apertures can be opened or closed depending on the air circulation desired. Wind can be driven into the indoor environment by opening the windward faces of the tower, or exhausted by negative pressure through openings on the leeward side of the tower. Today, with the increasing awareness of the application of natural ventilation as a passive means for cooling buildings and their occupants, the wind-tower vernacular is increasingly being used. Notable examples are the Visitor Center at Zion National Park, the campus at the University of Qatar, and the Saint Etienne Zenith Metropole.

3. PASSIVE DOWNDRAFT - A STRATEGY TO ACHIEVE NET ZERO ENERGY

With HVAC energy expected to be at least 40% of the building energy use, the net zero energy target relied on a low energy HVAC solution for the project. The goal of the design was to achieve savings of at least 50% when compared to an equivalent ASHRAE 90.1 compliant HVAC design for the building type. Passive downdraft was identified early on as a innovate means to achieving deep savings in HVAC energy while also providing excellent air quality. Many case studies of other projects that have tried passive downdraft have described water ingress, humidity and cooling capacity challenges with direct evaporative cooling. The passive downdraft concept adopted for the Conrad N. Hilton Foundation sought to avoid these well-documented issues by using cooling coils in the airstream at the top of the shaft instead of direct evaporative cooling. This would enable the natural ventilation airstream to always be conditioned in warmer months down to a supply air temperature of 18.3°C so that the system could maintain internal temperatures at 23.8°C at all times. This concept drew from precedents from existing buildings which had used cooling coils as part of a passive downdraft design.

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4. CONTEMPORARY SOLUTION DESIGN OVERVIEW

The architecture of the Phase-1 office building sets a precedent for the future phases of the campus. As the product of a sustainability-driven design process, the building is a minimalist architectural ensemble. All elements of the built form serve at least one, and in most cases two or more, performance-driven requirements that create a resulting environment that expresses the integrated systems that work passively to make the building an uplifting place to work. Through the careful use of natural materials—stone, wood, glass—the architecture attains a sense of warmth and textural richness.

The building's simple, rectangular form is sited East/West to optimize solar exposure and to respect the natural slope, enhancing the users' experience of the native hillside setting. The lucid, box-like form is eroded to allow views to nature and to admit daylight in diverse but controlled ways, creating a remarkably pleasant indoor environment. Further articulation of the form facilitates a dialog between building and site, with inhabitable outdoor spaces as extensions of the indoor environment, giving voice to the interface between the architectural form and the local landscape.

The narrow East/West bar parti is layered with offices and conference rooms along the North and South edges, optimizing daylight while minimizing unwanted solar gains. The office zones flank a double-height space that serves as a circulation spine as well as the social heart of the building. This inner atrium's ceiling is pushed up, admitting natural light via clerestory windows. The inner atrium sees additional controlled daylight and direct views out through glazing that opens to screened terraces at the East and West ends. The inner atrium also receives borrowed light from the perimeter offices through the use of internal clerestories, light shelves and tall, reflective ceilings. The windows on the building's south façade are protected using exterior roll-down dynamic solar shades. The shades are deployed by a computer clock, with a manual override located in each individual office. Protection from solar gains is an integral part of the building's performance, tying the design of the envelope intrinsically with the design of the building's passive conditioning systems. The shading system's high wind rating allows it to operate on hot windy days, which are known to occur yearly during the Santa Ana wind events.

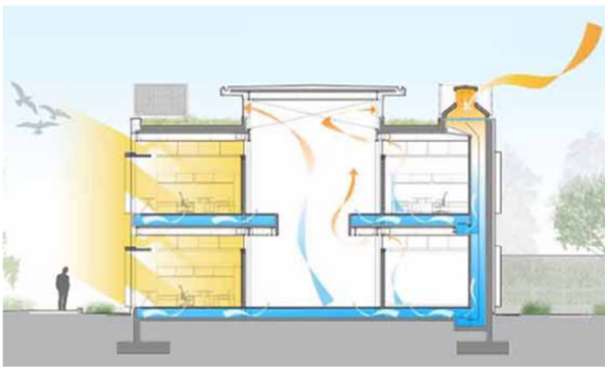
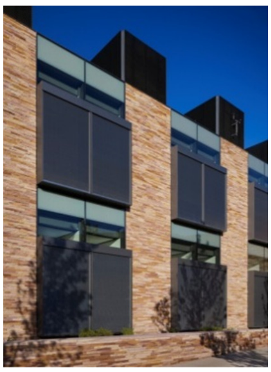
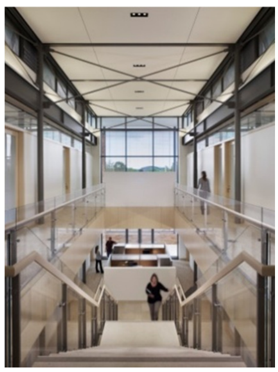

Fig. 2: Building section showing the passive downdraft and daylighting components of the facility.
Fig 3: Automated screens at south façade in lowered position. Fig 4: Air is expelled through digitally controlled clerestory windows at top of atrium.

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Daylight is the primary light source used for all work and circulation areas within the building. The natural daylight in each space gives building's occupants the ability to control the electric lighting by turning artificial lights off during daylit hours. Also, daylight sensors turn off electric lighting when adequate daylight is available. Visual comfort is optimized by exterior shading and also by redirecting and redistributing sunlight. Interior finishes with high reflectance were carefully selected along with accent colors and finishes, to achieve maximum reflected daylight along with visual character and warmth. Occupancy and daylight controls run in series in the larger open areas to maximize energy savings.

5. DESIGN CHALLENGES RELATING TO BUILDING ENVELOPE

There were three key architectural challenges in integrating a passive downdraft system into the building enclosure: Space, Air Distribution and Solar Gain. The airflow in a passive downdraft system is considerably slower than for a fan-driven conditioning system – about 1.0 m/s as compared with 5.0 m/s or more with a fan forced design. This placed added space requirements for vertical distribution of air on the project totaling approximately 2% of the floor area for air supply. To address the space issue, the perimeter C-shaped structural piers were integrated into the ventilation system. By also using the piers as the primary lateral support, the overall impact of shaft space and structure to the floor area was greatly minimized. This enabled spans that will provide long term flexibility in the floor plate.

The second challenge regarding passive downdraft is air distribution. Many other examples of passive downdraft had used vertical faced openings to distribute the air for cooling and ventilation. Given the way that the building was being broken up into enclosed office space, this was not particularly practical for the foundation. As a result, a raised floor system was used for not only the ventilation distribution but also for the distribution of data and power. This enabled a high degree of control over the distribution of air into different spaces within the building.

The final key challenge of the enclosure was solar loads. As the passive downdraft system provides 100% conditioned outside air, direct solar loads at times of high external air temperatures can dramatically increase the energy of the building cooling. On the south façade, automated external shades provide extensive solar control whenever there is direct sun and high external air temperatures. This control strategy enabled the building to address solar gain at times that it would cause a spike in energy use but also gave control to the users during cooler months where some direct sun may be desirable.

The passive cooling intakes represented a customized solution that had not been used before in California. In response, the design team developed a pre-fabricated prototypical design that would be built up in a factory in Mexico and shipped to the site for assembly. This helped ensure that during construction there was a minimal risk of damaging any components of the system.

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6. PATH TO NET ZERO ENERGY

The following table shows the expected performance of the facility as submitted for LEED. This shows that the expected energy usage of the facility is beyond net zero annually as the PV system can generate more energy than the building uses. One of the most significant energy saving gestures was to use passive downdraft, which on its own is expected to save the project over 100,000kWh in fan energy. The heating load in the design is also much lower than the baseline as the building has a 93 m² solar thermal array consisting of evacuated tubes and a 11,360 liter storage tank. This is expected to provide almost 70% of the hot water heating and all of the domestic hot water for the project. Another significant portion of the energy savings is due to the ability of the passive downdraft system to eliminate fan energy.

7. NET ZERO THROUGH M&V

The next step towards a sustainable future for the building industry is the measurement and verification (M&V) of buildings after occupancy. Though buildings are designed to meet high performance targets many often fall short of their goals as buildings are occupied and operated. This is due to the fact that energy models have to make many assumptions about how a building will perform. It is very common for buildings to have actual energy performance off by over 50% of what was modeled (Turner, 2008). This can be due to systems being left on and others running at low levels of performance. M&V in combination with advanced commissioning allow a design team to work with an owner to ensure a facility reaches its energy goals.

The M&V team has been working closely to monitor the building operation since occupancy. As part of this process the team has had regular post construction coordination meetings to resolve conflicts in the building. In addition to this, the commissioning agents are providing the data to the M&V analysts to use within calibrated energy models. This is required to be able to test the actual performance of the building compared to what was predicted through simulations. A typical M&V process is setup with data dumps from a BMS that are in a spreadsheet format, such as CSV. This data can be analyzed to look for performance trends of systems. The challenge with this approach is that it takes a significant amount of time to post process the data and find the links between the components that you need to compare. Figure 5 is a schematic diagram showing the transfer of information from the facility to the calibrated energy model. A unique component in the schematic is the use of analysis software that allows the team to interact with the data in an interactive and visual process. Many of the issues that have been found were found not through algorithms looking for relationships but through the visualization of graphs and charts which help to show issues with specific components.

The facility contains both an Alerton BMS system and electrical submeters that all directly communicate into a JACE system. The JACE is a data logger that takes all the information from all the different equipment and makes it usable with SkySpark, the analysis software used. SkySpark is setup on remote servers for the project collecting all of the information from the JACE and creating a large database that is used for analysis. As part of the M&V

plan seven rooms were given test shaft status with additional sensors to monitor the trending of performance in the shafts, raised floor and adjacent zones. The zones included typical conditions for the building including the boardroom, private offices and shared offices. These detailed zones provide additional information to assist in understanding how energy use in the passive downdraft system relates to occupancy trends. The measurement sensors and energy meters have been designed and detailed in coordination with the commissioning agent to be able to fully optimize the performance of these systems.

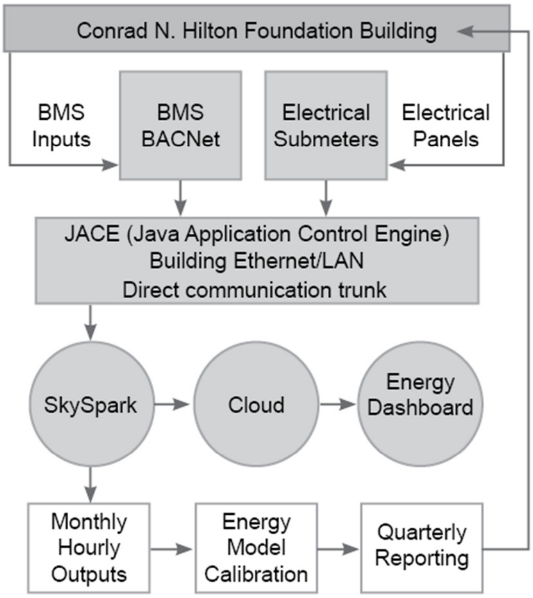

Fig. 5: M&V communication schematic.

	LEED Baseline (kWh)	CNHF Design (kWh)
Lighting	62,128	39,918
Space Heating	9,754	6,347
Space Cooling	54,746	7,328
Pumps	0	14,125
Heat Rejection	0	23,620
Fans	113,290	11,493
Service Water Heating	13,143	4,202
Receptacle Equipment	35,857	35,857
Elevators & Escalators	5,710	5,710
Total	294,628	148,600
Savings over baseline		50%
115kW PV Array Generation		167,449
Percent of Energy Generated On-Site		113%

Table 1: Modelled Energy Performance

At the time of writing this paper, three months of operational data had been collected for the project. The first quarter energy performance is currently being compiled as compared to a calibrated baseline energy model. The energy results published in Table 1 were established using Energy-Pro as part of the Title 24 and LEED reviews. Though Energy-Pro is a state-certified and LEED approved software, significant limitations exist in its ability to accurately model energy usage. This is partially due to its simplified controls. Currently the team is calibrating a new M&V IES-VE energy model. The building has been undergoing controls tweaks throughout the first period which has made calibrating the model very challenging. At this time, the calibration has not been fully completed and synchronized with the building controls.

Some key trends were clearly identified in the operational building data showing that spaces are generally being maintained within the desired comfort range of 21.1-23.9°C, PV and solar thermal outputs are in expected ranges and heating energy was higher than initially expected due to unseasonably cold weather. Through the analysis of operational data many items have been observed to require adjustments since occupancy. These have already made significant changes in the energy use of the facility. Aspects of system operation that have been changed as a result of the information provided by verification included morning warm-up controls, under floor heating coil controls, lobby heating coil controls, exhaust damper and window controls and solar hot water controls.

The common trend in all these adjustments is that they are all related to building controls. There are many challenges with designing, implementing and maintaining proper controls of building systems as the interrelationships of one decision can have big impacts on another and might not be so obvious. The controls of the passive downdraft system are critical due to the passive nature of air movement and its need for the right conditions to perform. The calibrated M&V energy model combined with SkySpark allow for improved commissioning (Visier & Buswell, 2010) based on energy performance rather than just equipment operation. These tools are allowing the team to make better informed control changes to improve the system's performance. During the M&V process the controls sequence has been updated a number times to accommodate different occupancy schedules than were expected and to optimize performance for occupant comfort during unusually cold weather in December and January. As a result of controls changes, heating energy for equivalent days has already been reduced by over 50% and much closer to anticipated energy usage levels. The project is tracking to achieve its net zero operating goal and it shows the clear value in conducting post-occupancy verification of performance on all projects.

8. CONCLUSION

The Conrad N. Hilton Foundation building is a great step forward in net zero design showing that enhanced natural ventilation through the design of the passive downdraft is possible in modern buildings. The net zero building will continue to be monitored for the next year to verify performance and share its lessons with the larger design community.

9. ACKNOWLEDGEMENTS
We want to thank the Conrad N. Hilton Foundation for their commitment to sustainability and using this building as a reference case for net zero buildings.

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The Impact of External Shading, Windows Glazing and Frame on Thermal Performance of Residential House in Abu-Dhabi

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ABSTRACT: *The amount of solar heat gain and thermal transmittance of the glazing and its setback are the main factors in windows thermal performance. External Shading devices contribute a lot in solar radiation reflectance. The present study aim is to determine the ideal design in dealing with solar radiation and heat gain through windows system, in order to improve existing building energy consumption. This target will be achieved through examining and analyzing different passive design parameters of residential villa in Abu Dhabi with the help of computer simulation (IES VE). Windows system properties and shading devices performance have a great impact on the energy consumption, peak load of mechanical cooling system, therefore CO2 emissions and thermal comfort. Based on that, the house annual cooling loads could be reduced by 10%.*

Keywords: solar heat gain, cooling load, external shading devices, window setback

1. INTRODUCTION:

Sustainable development needs have set one of the bottom lines of Abu-Dhabi 2030 vision, the capital of United Arab Emirates (UAE). Construction industry was prioritized in this vision due to the huge expanding and developments that have been carried on in the area. Construction and buildings industry are the cause of energy's massive demands in the area as residential buildings' energy consumption contributes around 45% of UAE's energy consumption. The present study significance is to enhance existing buildings thermal performance and at the same time improve regulators and buildings designers' ability to adopt energy efficient practices. Different passive design strategies effectiveness to be analyzed and evaluated in terms of energy saving and occupants comfort. The main focus is windows system with relation to buildings thermal performance. The amount of solar radiation and heat transmittance through transparent façade elements determine indoor thermal and visual conditions and thus energy demands.

Significant impact stated in many articles, dealing with buildings envelope characteristics and their relation to air-conditioning system demands and energy consumption. Al Shaali (2013) found out that triple glazing improves house energy consumption by 3% only**,** when compared to double glazing in house in UAE. Amin & Abu-Hijleh (2012) study of Dubai villa glazing assessment showed that the change from double low-e into triple low-e impact on energy consumption as 5% less. Sinha & Kutnar (2012) study stated that PVC frames showed better performance than Aluminum frames, thermally as well as environmentally. Chi-Ming & Yao-Hong (2011) finding is; Box shape shading has the maximum reduction effect, more than horizontal shades and vertical shades.

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Many other studies stated that the use of an appropriate glazing reduced the annual energy consumption the most, followed by shading devices (SDs) effect (Wong & Istiadji, 2004; Chi-Ming & Yao-Hong, 2011; Lai & Wang, 2011). A study conducted on residential buildings in Al-Ain, UAE found that window area and glazing system provide a considerable amount of energy savings, while SDs provide a limited reduction in terms of energy use (Radhi, 2009). On the contrary, Ebrahimpour & Maerefat (2010) found that using of the most appropriate overhang or side fin is more useful, for any direction of window, than advanced glazing systems. This is related to the fact that shading devices working principle is solar radiation penetration prevention while windows system works on two principles; solar radiation and heat conductivity reduction, based on low-e and U-value properties. This study will contribute to the current applications of the UAE sustainability pearl rating system “Estidama” and help to differentiate Passive Houses from traditional construction.

2. METHODOLOGY:

Series of simulations by an energy analysis program, IES VE, adopted in Kim et al. (2011), Bojic (2006), Yu et al. (2008), El Sherif (2012), and Ayyad (2011) studies. The last study stated that IES VE simulation program has the ability to integrate valid weather data, having a friendly user interface, and the flexibility to perform different types of simulations. This computer simulation software will be used to model the base-case house design at first, and then different scenarios will be applied to study their impacts on solar heat gain, annual cooling loads and energy consumption. This software has different modules that can perform different calculations for the same model but with specific data inputs.

An existing three-bedroom villa in Abu-Dhabi is the base-line case study. The villa’s ground floor area is 155m^2, and first floor area is 100m^2. The external walls are basically lightweight concrete blocks with external rendering and internal dense plaster. Total thermal transmittance; U-value, is 0.75 W/m^2.K, while roof’s U-value is 0.4 W/m^2.K. Existing windows glazing is double clear glass with aluminum frame. Windows thermal transmittance is 3.4 W/m^2.K, solar heat gain coefficient (SHGC) is 0.7 and light transmittance ratio is 1. No external shading devices applied to the current house design. Window to wall ratio (WWR) of ground floor is not the same as for the first floor, but the average WWR of the whole house is 0.16. Window to floor ratio (WFR) is constant in both ground and first floor; 0.28. East facing windows area is 59% of total windows area of the house. While south, west, and north facing windows area percentages are 19, 11, 11 % of the house total windows area, respectively.

Above mentioned numbers demonstrate how construction systems of most existing houses in Abu-Dhabi do not accommodate even Estidama one pearl. The minimum requirements of thermal transmittance U- value for one pearl Estidama are 0.32, 0.14, and 2.2 W/m^2.K for external walls, roof, and glazing, respectively. It is worth mentioning also that the Passive House according to the Germans standards should have: Triple glazing with two low-e coatings, “Warm Edge” spacers between the panes of glass, and Super-insulated frames. Passive House U-values for external walls, roof, and glazing are; 0.15, 0.15, 0.85 W/m^2.K, respectively.

- **Modeling Steps:**

Abu Dhabi City weather data file (latitude: 24.43∘N, longitude: 54.65∘E) was assigned during all stages of simulation process. Annual solar radiation and shading calculations of the whole building run by Sun Cast module and this is basically depends on Abu Dhabi’s sun path throughout the year. Thermal conditions inputs have been set through building template manager assuming energy saving in residents' practices. Domestic occupancy profile assigned for cooling system and people internal load as 50% daytime occupancy for non-holiday days.

Design temperature for cooling set point is 23^{o}C while no heating system considered due to the climatic conditions in the area. Relative humidity control kept between 30% and 70%. Air change rate profile follows cooling profile with minimum flow rate of 3.0 l/s.m^2. Infiltration gain set on continuously with external air maximum air flow 0.1 ACH. Internal gains were basically related to two factors; people (5 persons (sensible gain: 90 W/person, latent heat: 60 W/person)), and electrical lighting (fluorescent lighting with domestic lighting profile).

The next step was to assign construction materials as per existing building based on data collected from the project main contractor. Apache-Sim is a dynamic simulation calculates cooling load in the process of energy analysis and this was the reference scenario outputs. Using the same inputs, FlucsDL module used to examine the base-case daylight performance using CIE standard overcast sky and medium quality setting in order to consider SDs applications' impact on the assigned scenarios.

- **Assigned Scenarios:**

Building envelope characteristics, internal loads, interior lighting, ventilating, air conditioning, and occupancy profiles, in addition to weather data, are all unchanged throughout the simulation process. Windows shading condition, glazing and frame materials are the only varying parameters. Horizontal, vertical, and combination of them with two different projections; 30cm and 60cm, are the scenarios assigned in terms of shading devices design and their impact on thermal and daylight performance, in addition to energy consumption changes. Also, shading devices applied for south, east, and west facing windows based on aesthetical, technical, and functional aspects. As for windows' system scenarios, double clear, triple clear, double low-e, and triple low-e glazing with two different frame materials; Aluminum and PVC, are examined in terms of solar heat gain, cooling loads and energy consumption variations.

3. RESULTS AND DISCUSSION:

Reference scenario or existing case study annual energy consumption is 84MWh with cooling sensible load of 104.5MWh and solar heat gain of 22.8MWh. Windows' system in the reference "base-case" scenario is basically; double-clear glazing with Aluminum frame with no external shading.

- **Windows System Scenarios:**

Table 1 presents proposed scenarios in terms of windows system; glazing and frame. Studied glazing types have different configurations between double and triple panes, clear and low emissivity (Low-e) glass. Two frame material proposed; Aluminum and PVC. These scenarios proposed based on the mostly used and available materials in the market, thus most of construction professionals and stakeholders are familiar with these systems.

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Table 1: Windows' system scenarios and their properties

Windows Systems' Properties						
Scenario	Variables	U-value (Glass)	U-Value (Frame)	U-value (net)	SHGC	LT
1	Double-glazing, clear with Aluminum frame (Reference scenario)	2.85	8.3	3.4	0.7	1
2	Double-glazing, Low-e with Aluminum frame	1.97	8.3	2.6	0.64	0.76
3	Triple-glazing, clear with Aluminum frame	1.89	8.3	2.53	0.61	1
4	Triple-glazing, Low-e with Aluminum frame	1.28	8.3	1.98	0.56	0.76
5	Double-glazing, clear with PVC frame	2.85	2.1	2.78	0.7	1
6	Double-glazing, Low-e with PVC frame	1.97	2.1	1.99	0.64	0.76
7	Triple-glazing, clear with PVC frame	1.89	2.1	1.9	0.61	1
8	Triple-glazing, Low-e with PVC frame	1.28	2.1	1.52	0.56	0.76

Frame material change has a direct impact on windows system thermal transmittance. Table 2 shows the performance of windows' scenario in terms of solar heat gain, annual cooling load and energy consumption. Cooling sensible load (CSL) is directly proportion to windows U-value and SHGC together. The same relation applied to annual energy consumption. Based on this, the lower the U-value and SHGC are; the less in cooling demands.

Table 2: Windows' system scenarios and their performance

Windows Systems' Performance Summery					
Scenario	Variables	Solar Heat Gain (MWh)	CSL (MWh)	CSL Reduction (%)	Annual Energy (MWh)
1	Base Case _ Clear Double-glazing with Aluminium frame	22.89	104.56	0%	84
2	Low-e Double-glazing with Aluminium frame	20.58	101.98	2.46%	82.7
3	Clear Triple-glazing with Aluminium frame	19.83	101.35	3%	82.4
4	Low-e Triple-glazing with Aluminium frame	17.93	99.32	5%	81.3
5	Clear Double-glazing with PVC frame	22.89	103.2	1.30%	83.3
6	Low-e Double-glazing with PVC frame	20.58	100.56	3.82%	82
7	Clear Triple-glazing with PVC frame	19.86	99.92	4.43%	81.6
8	Low-e Triple-glazing with PVC frame	18.25	98.28	6%	80.8

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- **External Shading Scenarios:**

Table 3 shows external shading scenarios performance in terms of solar heat gain, annual cooling demands and energy consumption. As per literature review, shading devices (SDs) prevent solar radiation from heating up the internal spaces effectively and the same findings appear in the present study. Cooling sensible loads are directly proportional to solar heat gain values when it comes to SDs performance.

Table 3: External shading scenarios and their performance

Shading Devices' Performance Summery					
Scenario	Variables	Solar Heat Gain (MWh)	CSL (MWh)	CSL Reduction (%)	Annual Energy (MWh)
A	Base Case _ No Shading Devices (SDs)	22.89	104.5	0%	84
B	Horizontal SDs (Projection = 30cm)	20.84	103.1	1.33%	83.29
C	Horizontal SDs (Projection = 60cm)	19.29	102	2.39%	82.75
D	Vertical SDs (Projection = 30cm)	21.49	103.5	0.95%	83.52
E	Vertical SDs (Projection = 60cm)	20.42	102.8	1.62%	83.16
F	Combined H&V SDs (Projection = 30cm)	19.43	102.1	2.29%	82.8
G	Combined H&V SDs (Projection = 60cm)	16.84	100.3	4%	81.92

Horizontal shading devices (HSDs) showed better performance than vertical shading devices (VSDs), while the combined design between horizontal and vertical shading devices (H&V SDs) performed the best in terms of solar heat gain and cooling load reductions. Third column of Table 3 shows the impact of different configurations of SDs on solar heat gain. Horizontal, vertical, and combination between them at the 30cm projection reduced solar heat gain by 9%, 6%, and 15%, respectively, when compared to the reference scenario with no SDs. Doubling SDs' projection; from 30cm to 60cm, reduced solar heat gain value by 8%, 5%, and 13% in the same order. The combination between horizontal and vertical SDs impact on solar heat gain reduction is equal to the sum of the reduction outcome for each shading type individually.

At the projection of 30cm, HSDs, VSDs, and H&V SDs could reduce cooling load by 1.3%, 0.9%, and 2.3% respectively, while at 60cm projection the reductions percentage became 2.4%, 1.6%, and 4% in the same order. The comdined design between horizontal and vertical SDs with 60cm projection is the optimal external shading devices design proposed and resulted in 27% reduction in solar heat gain and 4% in annual cooling load.

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- **Glazing Vs. Shading:**

Family room has been chosen as a sample to examin the impact of proposed scenarios on a single zone and their functionality. Family room has different design charectaristic in terms of windows and orientations. It has south and east facing windows equal in the areas but south facing WWR is 33% and east facing WWR is 19%. Based on the difference in windows design and orientation between the whole house and Family room, a difference in performance of the same scenarios resulted.

In Family room, the optimal windows system and the optimal shading devices performed the same in terms of cooling load reduction percentage. In the whole house study, optimal windows system performed better than optimal SDs. This result is directly related to the change in WWR and orientation. Since south facing WWR in the family room is higher than east facing WWR resulted in enhancing the SDs performance. In Chart 1, comparsion between cooling load per m^2 of the whole house and the family room in four scenarios; base-case (1+A), optimal windows system (8+A), optimal shading (1+G), and optimal shading and windows system (8+G).

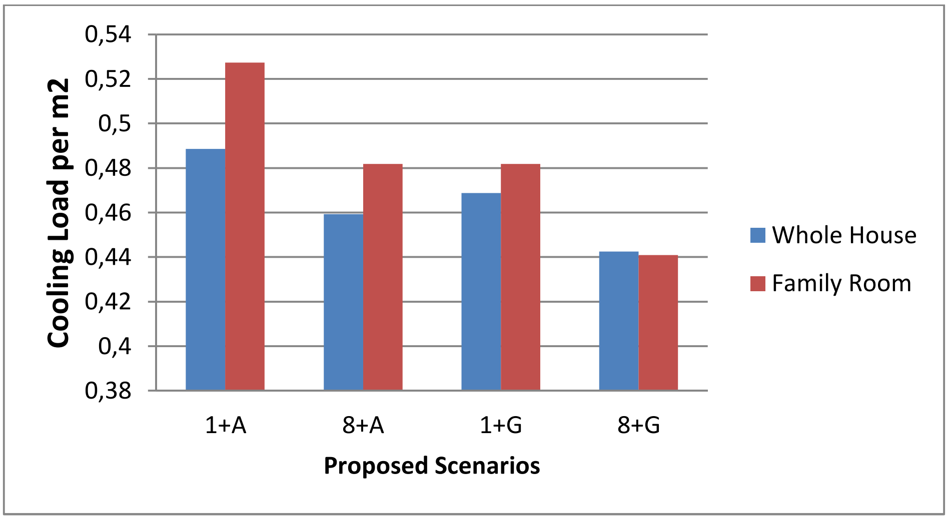

Chart 1: The impact of proposed scenarios on family room and the whole house cooling demands

- **Optimal Scenario:**

Triple glazing (clear + clear + low-e panes) with PVC frame windows system and combined horizontal and vertical shading devices with 60cm projection is the optimal proposed scenario. In comparison between reference and optimal scenarios performance; reduction of 41% in solar heat gain, 10% in annual cooling load and 6% in annual energy consumption achieved.

The optimal case scenario impact on cooling load was positive and the total reduction in demands were almost the sum of reductions resulted of applying each of windows system and shading devices individually. Therefore, no overlap witnessed from applying these two applications to the transparent parts of the house envelop, but their positive influences are actually accumulative. A future research study is to examine the influence of studied scenarios not only on thermal and energy performance but to include light and visual performance analysis in order to achieve the optimal energy consumption without compromising any of thermal or light comfort.

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4. CONCLUSION:

It is possible to reduce 10% of housing projects cooling bills in the UAE by adopting simple passive strategies which are applicable for existing projects also. The present study showed that 6% reduction in the houses annual energy consumption could be achieved. Therefore and based on a simple calculation, 2.7% reduction in the annual energy consumption of the UAE. Sustainable design principles can be simple and effective at the same time without adding much extra cost and sophistication to our architecture.

Shading devices (SDs) reduced solar heat gain effectively and more than windows system. While annual cooling load enhanced the most by improving windows system parameters; U-value and SHGC. Horizontal SDs performed better than vertical SDs while combined horizontal and vertical SDs was the best in terms of solar heat gain and energy demands reduction. Same windows system and SDs showed different impact on different house rooms based on their openings design and orientation.

In the present study, windows system optimal scenario tends to be Triple glazing with low emissivity pane and PVC frame. As for external shading devices, combination between horizontal and vertical type with 60cm projection performed the best when compared to other examined scenarios. However, case-by-case study and analysis is an essential part in determining the optimal configuration between external shading and windows system.

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Session 135:

Local Answers: a resource to face up to global challenges?

Chairperson:

López, Mª Isabel

Investigadora Depto Planificación y Diseño Urbano. Universidad del Bio Bio. Chile

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Affordable Sustainable Design:
Three Case Studies in California and Mexico

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California State Polytechnic University Pomona, & RTKL Architects, United States of America

Abstract: *This paper discusses the lessons learned in three faculty driven, student developed projects for communities in need in developed and less developed countries. The first project consists of two low energy prototypes to replace homes destroyed in California wildfires. The second project is a very low cost sustainable housing prototype for Tijuana, Mexico which emphasizes local materials and appropriate technologies for heating, cooling and water use. A prototype of the house was built by students and used to test multiple student developed systems over several years. The third project is a community center in Tecate, just south of the US-Mexico border, currently under construction, and that will provide skills training workshops for adults, daycare facilities, meeting spaces for the community, spaces for youth activities, and volunteer housing. It will also include low cost active and passive systems for residential use that can also contribute to the development of micro-industries.*

Affordable sustainable architecture, passive heating, passive cooling, informal settlements, architectural sustainable education

Introduction

In most developing countries, urban development in the last fifty years has been defined by the construction of very unequal cities, which are economically and socially divided and whose physical representation can be expressed in two different urban segments, the formal and the informal. Informal settlements represent well over one third of the urban population in developing countries, and in many cases they account for more than 60 percent of the total. Since the middle of the last century, most of the new households established in urban areas of developing countries are part of informal communities. In developed countries the informal sector is usually small or inexistent, but many times the cities are still divided into socially or ethnically segregated urban areas with widely differing access to basic needs, amenities, and services.

Climate change is a recent factor also affecting development in many countries. According to projections in the 2011 Human Development Report (UNDP, 2011), development in the world's poorest countries could be halted or even reversed by mid-century unless important steps are taken now to slow climate change, prevent further environmental damage, and reduce deep inequalities within and among nations. The report shows how the world's most disadvantaged people suffer the most from environmental degradation, including in their immediate personal environment, and disproportionately lack political power, making it more difficult for the world community to reach agreement on needed global policy changes. The report further emphasizes the human right to a healthy environment, the importance of integrating social equity into environmental policies, and the critical importance of public participation and official accountability. Emerging design professionals should have the skills to address these global issues and social responsibility has been integrated in courses to engage students in real projects, providing them with the knowledge that will carry over into their professional careers. Furthermore "New directions in design and architecture don't occur

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accidentally, but always arise out of real changes in society, cultures and concepts (Papanek, 1995).” It is clear that this is one of such moments and approaches that are responsive to ecological considerations, going beyond simple appearance or ‘cosmetics’ are required. Furthermore it is important to design not only socially and ecologically responsible buildings but also to design the systems in these buildings, including those that help to achieve the comfort and well-being of its users and serve ‘real needs’ of the human beings that use them.

Prototype Homes for Emergency Response in California

During the 2007 California wildfires, 1,350 homes were destroyed or damaged and 15 people died in San Diego County. The fires lasted for three days and burned 300,000 acres in San Diego County alone. These fires affected the entire state of California; the Governor declared a state of emergency in seven counties, and the president ordered federal aid to supplement local response efforts. The Department of Architecture at Cal Poly Pomona collaborated with HMC Architects to design and build two homes to replace those destroyed in the 2007 California wildfires. However, more importantly, these are prototypes that can be implemented in response to similar emergencies in Southern California. The homes would be owned by the City and rented to ranchers who maintain the land, and qualified for funding from the Federal Emergency Management Agency (FEMA).

Figure 1: Projects selected for further development at the end of the Pamo Valley design studio. Students: Brandon Ro & Aaron Locke; Dimitrios Tolios & Parinaz Behbahani

This project was also awarded one of three 2010 NCARB Grants, which are designed to help architecture schools implement new programs that merge the practice of architecture and education in a studio or classroom setting. This was achieved by bridging the concepts of the practice academy model and transdisciplinary methods to form the Transdisciplinary Practice Initiative (TPI)—a pedagogical shift that supports a co-lecture classroom environment between practitioners and scholars using the Pamo Valley Project as a case study. The TPI

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was organized into four phases: design, paid internship, construction, and post occupancy analysis, with each phase shifting the classroom's location.

Students in the first course, a design studio, designed two low cost sustainable homes. During this studio, practitioners from local firms worked in tandem with faculty in the university classroom. Studio time was divided into three parts: faculty instruction; practitioner instruction; and studio integration where both faculty and practitioners engaged in one-on-one discussions with student teams. In the studio integration phase, students balanced design issues with energy simulation tools using a carbon neutral protocol (La Roche, 2012) to design low energy, low carbon prototypes. During this studio students presented their designs to their peers, faculty and collaborating practitioners. Two projects were selected to carry over to the spring course for further research (Fig 1). Most students proposed climate responsive buildings with modular construction systems, with a focus on prefabrication, and adaptable to different configurations, while reducing the assembly time.

More detailed work, including development and experimental research and testing of the different systems, continued in a research seminar in the spring following the design studio (Educate Award, 2012). Later, in the summer of 2011, two students received paid internships to work at HMC Architects and develop the construction drawings for the houses, providing unique opportunities to integrate in-house cost estimators, quality control specialists, specification writers, and financial staff to work with students during this phase. Complete construction documents including energy calculations and structural documents were developed as part of this process. The projects were not built due to lack of funding but they demonstrate that it is possible to design low cost, sustainable, well designed alternatives to FEMA houses that are also adapted to local climate and conditions, and with the potential to become replicable alternatives for fire prone areas in Southern California.

Tijuana Prototype House

The Tijuana House project was developed in collaboration with Corazon, a U.S. non-profit organization whose mission is to serve the poor in Mexico through an active home-building program, educational programs, and other community development activities, most of them close to the border (Fig 2). Corazon's home-building program is effective in providing much needed shelter for residents of the communities in which they work. Chief advantages of their designs include a low cost as well as relative ease of construction, allowing unskilled volunteers to construct these units in a single day. However, to achieve this low cost method of construction, the designs rely on imported, non-renewable materials, do not consider heating and cooling needs at all, and do not address water, sanitation, security, and food production. In short, there are more sustainable approaches that could enhance quality of life for the homeowners but that need to operate under the conditions faced by relief organizations: affordable, easy to build, and desirable for local residents.

Figure 2: View of a Tijuana hillside and Corazon volunteers working in Tijuana

Working within the parameters of the Corazon home-building program, the faculty-student team designed and tested prototypes that emphasized materials readily available within Tijuana such as garage doors, bricks, plywood, earth, and even tires and stone for retainment walls in the abrupt topography. A driving motivation for research was the integration of technologies and the examination of how outputs from one system could become a resource for another system; for example the gray water from washing for irrigation. Dwellers in these communities cannot afford mechanical heating and cooling systems, so passive cooling and heating systems are required for health and comfort, there is no other option.

Technology also had to be appropriate for the cultural and economic conditions of the community, especially regarding cost, perceived value and security. The owners had to be able to afford their homes, and feel safe in them while also being proud of the place in which they live. Thus, the homes were designed to provide flexibility, potential to grow, and adaptability to steep topography. The prototype was designed to grow with the family and have spaces that could be used for different purposes (Fig 3). Tires and gabian walls were proposed to adapt to topography and papercrete as a low cost alternative construction method for the walls (Fig 4). Residential and community food production alternatives were also proposed and integrated in the lot.

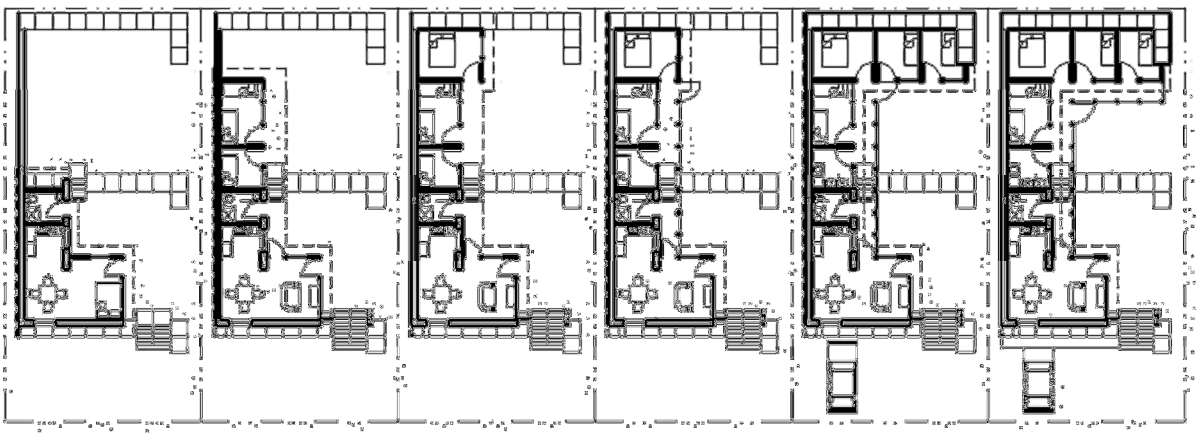

Figure 3: Growth and Flexibility in the Tijuana House Prototype

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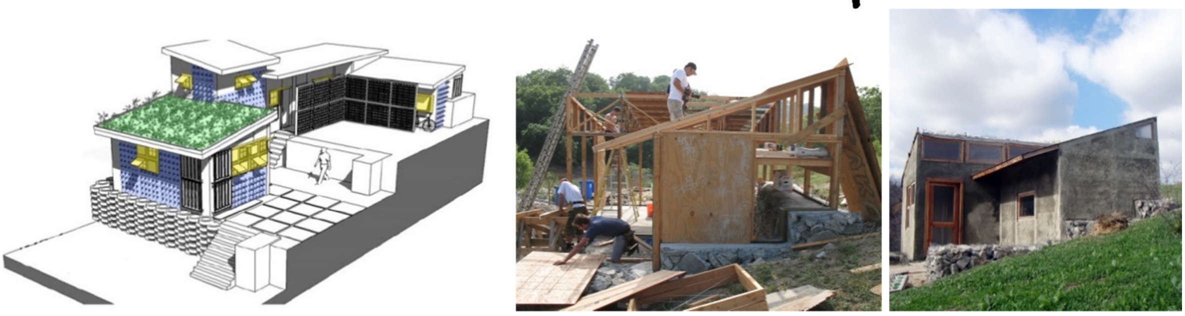

Figure 4: Prototype home under construction by students at the Lyle Center and views of the house.

A modular frame was used to support the testing of multiple systems developed by Faculty, NGOs, undergraduate and graduate students that have been published in different technical conferences. Among them are a low cost green roof, papercrete walls comprised of waste paper and cement, low cost windows, solar walls, a solar hot water system, a solar radiator, heating with composting, gray water system, rain water harvesting,

Cerro Azul Community Center

This project, in collaboration with Corazon, a California based NGO, is a design for a low cost environmentally and socially sustainable community center for the people of the Cerro Azul community, close to Tecate, Mexico. The center will provide skills training workshops for adults, daycare facilities, meeting spaces for the community, spaces for youth activities and volunteer housing. The NGO wanted the center to be built in phases, so the students proposed a cluster of buildings that could be built individually with the help of the community, volunteers and students (Fig 5). The same sequence was implemented: first a design course in which students designed buildings with active participation of the clients and the community, and later seminar courses in which they used experimental research methods to study the impact of one or more identifiable variables on the phenomenon under study: this involved designing, building, and testing a real system and then analyzing the data.

Figure 5: Student projects by Barbara Gonzalez & Hailey Peitzman (selected by the clients and community) and Leina Naversen (runner up).

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Figure 6: Students in discussions with the community to understand their needs and aspirations and construction of the Community Center's storage facility in Cerro Azul.

An important part of the design process was the active participation of the community. Techniques such as climate analysis and site visits permitted to have a better understanding of local conditions while meetings with the community permitted to better understand their needs and aspirations (Fig 6). The community and client were also involved in the design process through student meetings and proposal reviews. Even as construction is ongoing, (Fig 6), the different active and passive systems are being further developed and tested in California by another group of students for performance and viability. Each team of students focused on specific issues such as water, energy, waste, or materials, and proposed a solution. Some of the systems developed and tested include: alternative carbon reducing strategies such as a rain water harvesting system, a low cost solar hot water system, variable insulation-shading window; low cost passive cooling systems such as roof ponds, radiators, cool towers; phase change materials; and passive heating systems such as direct gain systems, trombe wall systems, and water wall systems. Some of these such as the evaporative cool tower and a solar chimney are being further refined, and integrated in the building to provide passive heating in the winter and passive cooling in the summer (Fig 7).

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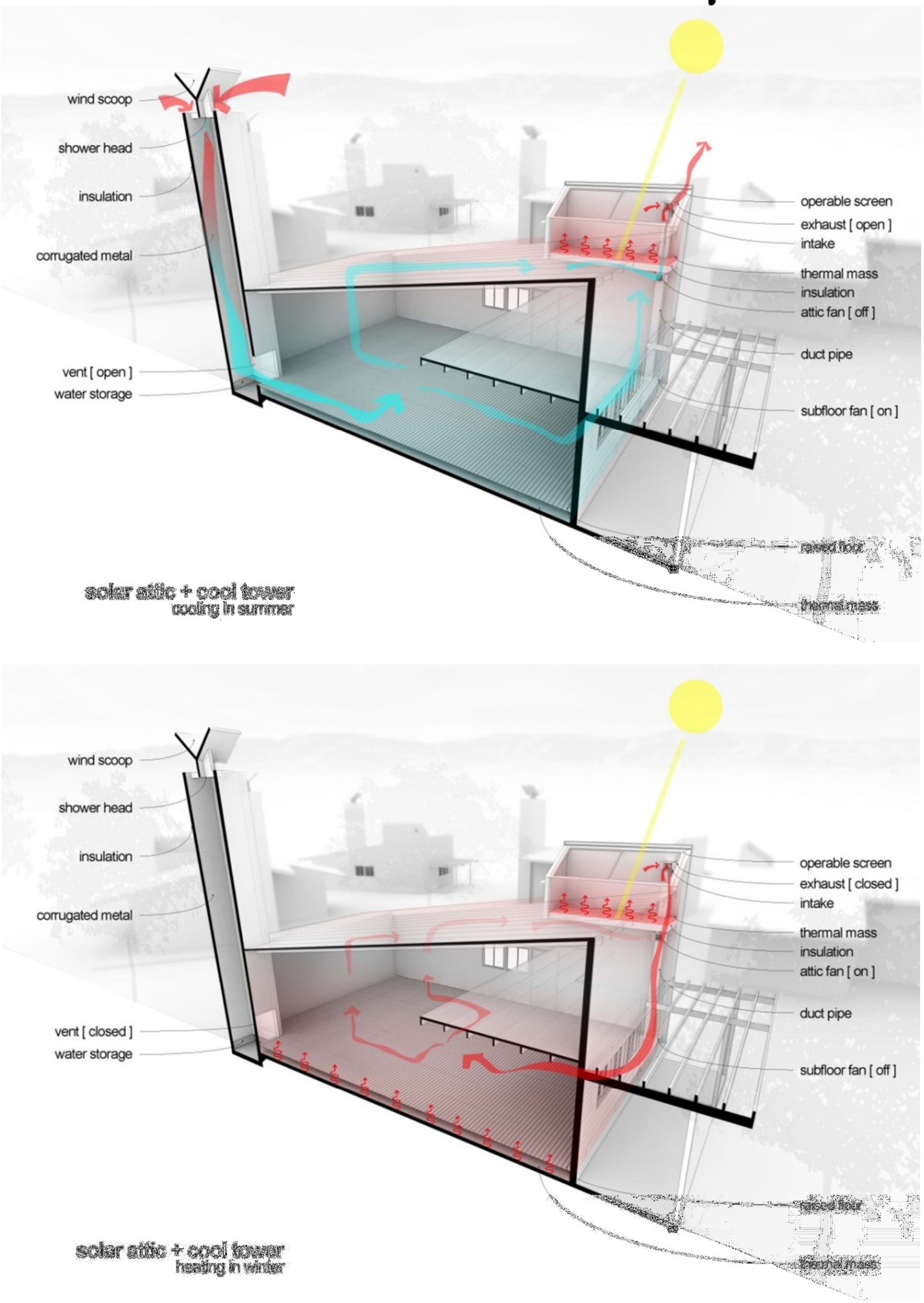

Figure 7: Summer and winter heating and cooling system performance with the cool tower and solar attic in a community center building. Students: A. Oliver, C. Aguilar, Z. Lam, B. Gonzalez (solar attic), C. Reed, M. Hamagami, T. Pham, B. Shiang Lin (cool tower).

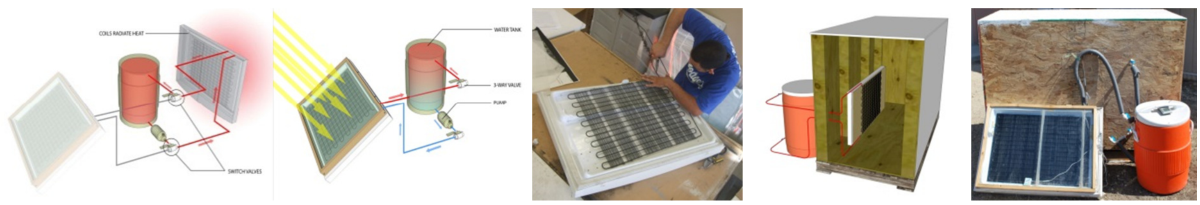

Figure 8: "Zero Dollar" Solar Hot Water system using refrigerant coils from a refrigerator. Students: Erica Christie Obertelli, Mark Erler, Felipe Ortega.

Conclusions
All three projects demonstrate how the impact of an academic and practice led curriculum have resulted in a heightened student awareness of real-world problems. Because of time constraints, students in a quarter long courses typically do not have time to develop an idea to the level in which it can be thoroughly tested. Because some courses were part of a larger project in which work was developed before, during, and after the quarter, they were able to develop more sophisticated work. By participating in these projects, even if it was sometimes difficult because of multiple constraints such as difficulties to authorize travel to Mexico, or student building, students learned more than they would usually learn in a typical quarter or semester project in a classroom.

The two projects in Mexico also suggest that the path to sustainable architecture does not have to be the same everywhere in the world, and varies as a function of social, cultural, economic and environmental differences. When HVAC systems are not commonly used in a community, it should be easier to implement other low energy comfort strategies and develop alternative paths to the established energy intensive systems common in developed countries. I expect to continue research to investigate if this path can be provided with alternative low cost passive and active systems that could be used to improve building performance, while contributing to develop a contemporary architecture that maintains traditional values and is respectful of its environment.

Acknowledgements
To the City of San Diego and National Council of Architectural Registration Board NCARB for support of the Pamo Valley Project. To HMC Designing Futures Foundation and Traylor Brothers for financial support for the Cerro Azul Community Center. To Corazon for allowing us to collaborate with them. To the Lyle Center for Regenerative Studies and the Habitat 21 initiative for support of the Tijuana House Prototype.

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Environmental assessment of a constructive system for living spaces made in Mauritania

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Abstract: *An elementary living space, developed by ICHaB, is evaluated. Different solutions of ´Basic Habitability', have been constructed from it (schools, housing, medic care centres...). It consists of a structure (foundation, pillars and beams) of reinforced concrete and enclosing walls executed with different types of materials that may be local (gypsum block, adobe ...) or imported (concrete block). The cover is made as a 4 cm thick concrete catenary vault.*

The paper attempts to explore the environmental analysis of the 'module' from the perspective of sustainability assessment. Different constructive solutions are characterized with a focus on life cycle. The links with social, cultural and economic aspects have been incorporated into the analysis of different spatial solutions. The detailed inventory data from the case study project and the impact assessment focuses on resource depletion (kg, MJ, kW) and global warming (CO2eq)

Key words: LCA, environmental-impact, development cooperation, Africa

Introduction

The use of concrete as exclusive material is replacing the traditional use of local materials in latest urban developments in Africa. The concrete represents the idea of modernization in the collective unconscious of a population in need of progress, even though the traditional systems take advantage of centuries of adaptation to extreme weather conditions. The current paper aims to work on the appropriateness of the use of local materials by analyzing their impact throughout their life cycle.

The housing solution proposed for Mauritania by the Instituto de Cooperación en Habitabilidad Básica (ICHaB) of the Universidad Politécnica de Madrid, has been used to build many different buildings throughout the country by the aggregation of simple components (Image 1).

Image 1. Basic component; Dwellings at Nouakchott; Health center in Tellaba. Source: José Javier Legarra

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The construction system allows having facades of different materials depending on availability in the environment (plaster, stone, adobe ...) over a structure of pillars and roof concrete vaults (Legarra et al., 2009). This results in some environmental implications that should be studied for each case on its specific location.

Case study: El Mina school

This paper focuses on the analysis of an existing building constructed in 2008: the classrooms for El Mina school for sensory disabled children in the city of Nouakchott, in the Sahara desert.

The building is designed for a bioclimatic operation in desert climate. High ceilings are projected and solar incidence is especially controlled by surrounding circulations equipped with sunscreens that allow cross ventilation (Image 2). The impact of building enclosures for different solutions is evaluated.


.
Image 2. Classroom module for El Mina school; Source: José Javier Legarra

The structure is constructed of reinforced concrete and the walls and partitions are made with gypsum blocks. The design attempted to use local low impact materials as far as possible. Imported materials were used in the structure in order to ensure structural safety according to the function of the building. Local materials were used for the enclosure: in this case the gypsum from a local factory. Nouakchott has one of the largest deposits of this material in the world, although its use in construction is limited merely to plasters and decorative elements. The blocks were hand made in the plot itself using steel moulds.

It's hard to find gravel around the sandy Nouakchott. This makes this arid be very expensive due to the cost of transport from rocky areas within the country. For this reason, the usual existing local aggregate is used: the seashells. Concrete made with this aggregate has a lower compressive strength (Revuelta et al. 2008) (Garcia et al. 2009), which requires to reinforce the structural elements with a higher amount of steel.

The data of the density and weight of the materials used for concrete production were obtained from tests performed at Instituto Eduardo Torroja in Madrid (Garcia et al. 2009) and gypsum blocks were tested at materials laboratory of Escuela Técnica Superior de Arquitectura (Villanueva, Oteiza 2002). Construction materials were imported from Mauritania to perform both studies.

The analysis is summarized in the following chapters, taking into account the principles and guidelines of the standard ISO14040.

Goals and Scope

Being aware of the limitations of this type of analysis, the objective is not set in the accurate quantification of environmental performance. The study is aimed to raise various issues relevant to the study of impacts on this kind of projects, indicating environmental issues traditionally outside the decision-making.

The proposed methodology provides some results that allow us to evaluate solutions with local materials (gypsum, earth, stone, shells) versus imported materials (cement, steel, aggregates) in West African countries. Another aim is to understand the life cycle phases associated with higher impacts (raw material extraction, transportation, manufacturing, construction, use, maintenance and end of life).

The functional unit corresponds to the use of a structure and envelope of a classroom block consisting of 8 modules in Nouakchott for a period of 30 years. This communication focuses on the evaluation of different solutions for the enclosure. The reduction of impacts that meant replacing conventional concrete block walls by local gypsum blocks are quantified and compared with the impact of the structure.

As system boundaries, the extraction, processing and transportation of raw materials, the placing and the stage of use and maintenance have been considered. It also outlines the end of life scenarios.

Resource depletion (kg, MJ, kW) and global warming (CO_2 eq) were taken as impact categories. The presentation is focused on CO_2 emissions.

Inventory of materials from cradle to gate

A systematic accounting of the different items from the construction of the building is made, and an estimate of the origin and mean distances of each of these materials have been calculated.

Some results are shown in the results data tables (table 1 and 2). Using data referenced by the carbon inventory developed at the University of Bath and the database Ecoinvent and ELCD. We have tried to take the data that best conform to the local reality, characterized by the following conditions:

- Both cement and steel are imported.
- As the seashell is an understudied material, equivalent aggregate data is assumed.
- Dune sand is used, very different to that commonly used in Europe
- Gypsum comes from local production
- Water is a scarce resource in the area and it is transported by tanker

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	Mass (kg)	EMBODIED ENERGY MJ/Kg	EMBODIED CARBON $KgCO_2/Kg$	EMBODIED ENERGY MJ	EMBODIED CARBON Kg CO_2	Origin	Means of transport	Dist. Km	Kg CO_2eq
Sand (general)	73.086,19	0,100	0,005	7.308,62	365,43	Nouakchott	Lorry*	2	6,62
General aggregate	50.922,50	0,100	0,005	5.092,25	254,61	Nouakchott	Lorry*	10	23,06
Portland CEMI	15.326,12	4,600	0,830	70.500,14	12.720,68	Average distance	Freight ship	3.754	1.421,1
Water	20.141,96	0,200		4.028,39	0	Idini	Lorry*	45	41,05
Gypsum (general)	10.970,33	1,800	0,120	19.746,59	1.316,44	Nouakchott	Lorry*	2	0,99
Iron (general)	3.908,00	25,000	1,910	97.700,1	7.464,29	Algeciras. Spain	Freight ship	2300	222,01

* Operation Lorry 3,5-7,5t (euro 5). Full lorry, 7t

Table 2. Inventory data summary of the main materials and transportation to the building work site. (ICE 1.6a and ECOINVENT + IPCC GWP 2007 20y)

Use stage

The benefits of thermal comfort during the use phase have been evaluated by the building energy simulation (Image 3). This allows also to evaluate the impact of energy consumption that would occur in case of installing air conditioning facilities to keep the classrooms within an acceptable thermal comfort by Western standards

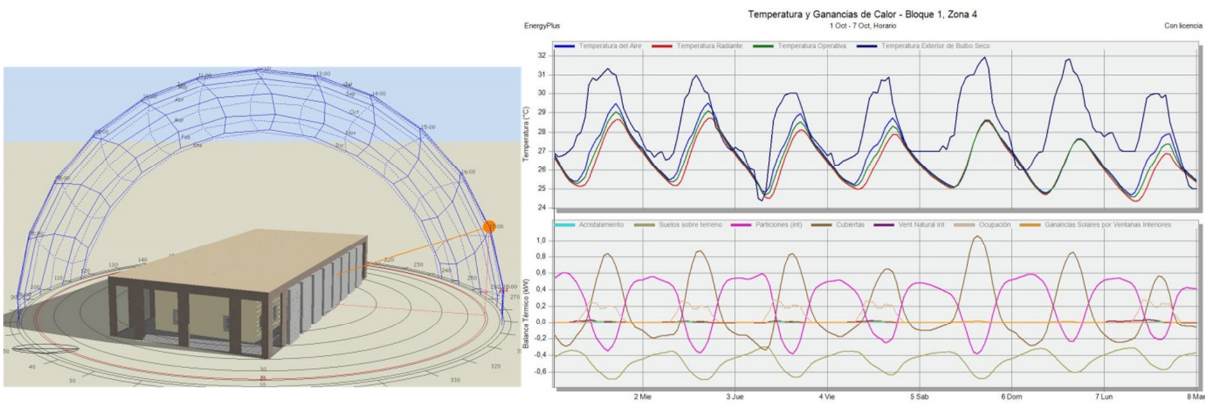

Image 3. Model and results for the energy simulation

In this case, the lack of means does not allow consumption of energy for classroom air conditioning. Therefore, the study of living space comfort based on air temperature remains interesting. The simulation allows to evaluate building elements that improve thermal comfort (such as sunscreens and ventilation), and those that worsen (roof). Building design reduces indoor temperature in the living areas an average of 3°C below the outside temperature in summer week

To avoid energy consumption in lighting, a daylighting system is designed. It is based on the inclusion of inverted tea glasses in the thickness of the concrete vaults.

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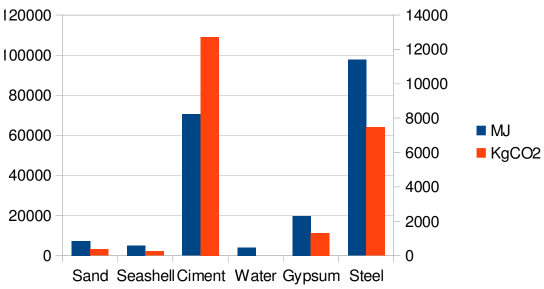
Image 4. Installation of tea glasses in the dome, view from the inside and solar protection jalousies.

It is important to correct the usual deficiencies in the maintenance of buildings in such projects. A guidance manual "Conseils pour l'Utilisation du Bâtiment et entretien" is delivered to users, and a training on general recommendations is provided to local workers in order to ensure durability of the building.

Impact assessment

The largest amount of material corresponds to the sand. The highest global warming potential and energy consumption correspond to cement and steel (Image 5). The analyze of these items in detail reveals the greatest impact is caused by materials used for the structure construction (Image 6). This impacts correspond to lean, foundations and structural concrete, as well as steel.



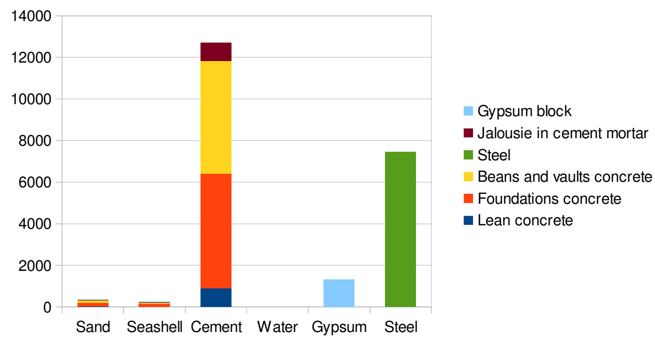


Image 5. Embodied carbon and energy of the major materials; Image 6. Embodied carbon for building elements

Regarding the transport of materials, the distances travelled by imported materials are higher, but the boat transport is more efficient than truck transport used locally.

No impacts associated to energy consumption where taken into account for the use stage.

Interpretation

Both data collection and the choice of the database to define the inventory has not been easy. Even though there are no full life cycle data of studied materials, some interesting results can be observed. Used materials are common but in most cases it was necessary to adjust the amounts and simplify processes. Most of the data found don't take into account local specific problems. As an example, used methodology tend to assume the use of machinery for mortar, concrete or plaster production, but all of these products are handmade in the case study.

All references that have been necessary to allow traceability of data have been incorporated. The critical review of used data highlights the need for local data. Some of the references used also have a high degree of uncertainty and may lead to inconsistencies which may be taken into consideration, although they have been tested in multiple databases.

Conclusions

The collection of data needed for the analysis was not easy. There is no data available for the entire life cycle of studied materials. Although they are materials of most common use, found data are alien to local problems.

The greatest potential for global warming and higher energy consumption used in the manufacture of materials are due to cement and steel. Regarding the transport of materials, the distances traveled by imported materials are much higher, but the boat transport is more efficient than trucking used locally.

With regard to energy simulation, only climatic data from 12 of the 49 African countries are found on the 'energy plus' website. Data corresponding to Mauritania climate were not found. The climate data used are those from Dakar (Senegal). However it is found that the building's design manages to improve thermal comfort, cushioning high outside temperatures inside the classroom.

Having greater influence than energy consumption in development projects, impacts associated to materials inventory should always be taken into account.

The need for a simplified methodology for the environmental assessment, which is still under surface design is confirmed.

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Applications of Sustainable Factors in Floating Architecture

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Abstract: *This paper aims to investigate the applications of sustainable factors in floating architectures and to suggest some reference ideas for new projects. The applied sustainable factors in floating architecture by 3 dimensions can be summarized as follows; water resilience, renewable energy, PCM, local material, preservation of natural environment in environmental dimension; long-term usage, water reuse & treatment, natural ventilation, thick insulation in both environmental & economic dimensions; relocatable, prefabrication & modular design, heat recovery system, insulation made of recycled paper in economic dimension; solider security against crime, peaceful atmosphere, place-making, community development, livability, social support, community resilience, high sense of community in social dimension. Floating architecture has been emerging as a sustainable alternative around the waterside region, and can be regarded as one of the most sustainable building types if proper sustainable factors would be applied.*

Sustainability, Sustainable Factor, Floating Architecture, Climate Change

1. Introduction

Nowadays floating buildings can be found with easy round the world. There are almost every kind of floating building types such as individual house, row house, exhibition hall, restaurant, visitor center, ferry terminal, stadium and hotel.

As Climate change like global warming advances, level of sea rises and severe flooding sometimes results. Usable land in urban area becomes less and the price is rising due to continuous expanding development. And people want to enjoy the activities on water rather than on land according the improved level of living.

This paper aims to investigate the applications of sustainable factors in floating architectures through the analysis of samples and to suggest some reference ideas for new projects. Research method includes the site-visits, the review of related literatures, and the navigation of some homepage.

2. Concept of Floating Architecture and Sustainable Factor

2.1 Definition of Floating Architecture

Floating architecture can be defined as a building for living/working space that floats on water with floatation system, is moored in a permanent location, does not include a water craft designed or intended for navigation, and has a premises service system (electricity, water/sewage and city gas) served through connection by permanent supply/return lines between floating building and land, or has self-supporting service facilities for itself.

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2.2 Concept of Sustainable Factors

Sustainability can be defined as the capacity to endure. Sustainability is improving the quality of human life while living within the carrying capacity of supporting eco-systems. For humans, sustainability is the potential for long-term maintenance of well-being, which can have environmental, economic, and social dimensions [1].

Environmental sustainability involves making decisions and taking action that are in the interests of protecting the natural world, with particular emphasis on preserving the capability of the environment to support human life [2]. Economic sustainability is the term used to identify various strategies that make it possible to use available resources to their best advantage. The idea is to promote the use of those resources in a way that is both efficient and responsible, and likely to provide long-term benefits [3]. The concept of social sustainability encompasses such as social equity, livability, health equity, community development, social capital, social support, human rights, labor rights, place-making, social responsibility, social justice, cultural competence, community resilience, and human adaptation [4].

3. Sample Floating Architectures


Figure 1 & 2. Floating Pavilion & IBA Dock

3.1 Floating Pavilion, Rotterdam, Netherlands, 2010

The Floating Pavilion (see Figure 1) in Rotterdam has a complex consisting of three floating half-spheres with diameters of 18.5, 20 and 24 meters respectively, and with total floor area 1,104 square meters. The pontoon is made of expanded polystyrene (EPS) combined with a grid of concrete beams.

Solar thermal collectors & absorption material on the roof and Phase Change Material (PCM) in wall liquefy/solidify when the auditorium warms up/cools down. The geodesic domes are covered with extremely lightweight ethylenetetrafluoroethylene (ETFE) foils. The foil-roof consists of three layers, filled with air under pressure for insulation. Air convection streams are created between windows on ground floor level and in the top of the roof. Waste water is purified and reused for flushing toilets. Even the toilet water is purified and discharged into the surface water [5].

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The entire facility is designed to accommodate approximately 500 visitors. And the auditorium can be used for groups up to 150 people. Various conferences and social events can be available with its remarkable shape as a landmark.

3.2 IBA Dock, Germany, 2009

The IBA Dock (see Figure 2) as the information and event center is constructed upon a floating pontoon. The building is being used for Urban and Architecture information center in Hamburg.

The IBA Dock has 3 storeys and 1,640 square meter floor area. The building is situated on an approximately 43m long and 26m wide concrete pontoon, and the superstructures are made of steel in prefabricated modular construction. The building is setting new standards in the area of climate protection such as 25cm thick insulated outer walls

The building is based on “zero balance concept”, which focuses on solar energy management and systems that provide buildings with sustainable heat and cooling all year round. 16 solar thermal collectors with about 34 square meter on the roof are positioned facing south.

Together with solar energy, some more energy is drawn from the Elbe using a heat exchanger built into the base of the concrete pontoon. This provides both the heating and cooling requirements for the water and air conditioning of the building through ceiling fixtures.

The heat pump, along with a ventilating machine that provides air exchange for the entire building, are powered by 103 square meter of south-facing solar photovoltaic(PV) modules located on the roof terrace and angled at 30 degrees. Because the electricity needed by the heat pump is covered by sloar PV cells, no further cooling or heating energy is needed [6].

3.3 Autark Home, Netherlands, 2012

Autark Home (see Figure 3) is a self-sufficient and passive floating home with European passive house certificate. The floating home has 2 storeys, 109.4 square meter floor area, outer wall with 55cm thick massive EPS, isolated windows and doors, triple glass and no cold bridges. There is an ioloated water tank with capacity of 4,000 liters and 6 solar thermal collector panels on the roof to keep the temperature of 70 to 80 degree for 4 to 5 days [7].

River water is converted to gray water through a filter. And high-quality drinking water is purified through reverse osmosis in combination with the sand and UV filter. Before the waste water returns to the river, the water is cleaned for 90% by a built-in filtration system. The incoming fresh air is heated or cooled by outgoing exhausted air through a heat recovery ventilation system.

The electricity is supplied by 24 solar PV modules. The electrical energy is stored in 24 batteries, supplying enough electricity for 4 days for a normal family. The system can deliver 5,300 kWh a year. On the display of the monitoring system in living room,

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solar production can be watched. In bad weather condition, a bio-diesel generator supplies the home with additional power.


Figure 3 & 4. Autark Home & Makoko Floating School

3.4 Makoko Floating School, Nigeria, 2013

Makoko Floating School (see Figure 4) is a prototype floating structure with area of 220 square meters, built for the historic water community of Makoko, Lagos, Nigeria. As a pilot project, it has taken an innovative approach to address the social and physical needs of the community considering the impact of climate change and a rapidly urbanizing context.

The overall composition of the design is a triangular A-Frame section, with the classrooms located on the second tier. They are partially enclosed with adjustable louvered slats. There is a playground below, and the roof has an additional open air classroom.

It is designed to use solar PV modules, to adapt natural ventilation, to recycle organic waste and to collect rainwater for the toilet. Bamboo and wood from the local community are used as the main material as the structure, support and finishing for the completed school. The whole structure sits on a base of typical plastic barrels. The barrels at the periphery can be used to store excess rainwater from the catchment system [8].

3.5 Brockholes Visitor Centre, UK, 2012

A new nature reserve named Brockholes (see Figure 5) was created from the abandoned remains of a quarry near Preston, UK. The 1,400 square metre floor area building sits on a 2,795 square meter concrete pontoon. The center comprised a cafe, conference center and education facilities as well as an exhibition space and retail shops. The highlight is the beautiful floating eco-village with decks for visitors to enjoy the peaceful surroundings.

Brockholes sits on a buoyant concrete raft, held by four steel posts to stop it drifting across the lake. It can rise up to 3 metres, which would only be necessary in a catastrophe, but will regularly rise up and down by 40cm over a year because the site is prone to flooding with a one-in-100-year risk of up to 3 meters and has an annual water level variation of 40cm [9].

The architect designed high, steep-pitched roofs enclosing large volumes (good for air circulation and extraction), clad in oak shakes – rough tiles. Gutters are made of copper (long-life, recyclable). Grey water system and woodchip boilers add to the green scores. Ventilation

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is entirely natural. Insulation is a cheap but effective material made from recycled newspapers.

The facade is an environmental system, helped by external awnings which provide the best form of shading in summer. The low-level window seats means that efficient natural ventilation and views out are not obstructed. In winter the internal space can receive maximum daylight and passive solar heating. The deck now sits above the water with a freeboard of only 150mm, giving the feeling of intense proximity to the lake.


Figure 5 & 6. Brockholes Visitor Center & Oregon Yacht Club

3.6 Oregon Yacht Club, Portland, USA, 1910

Oregon Yacht Club (OYC, see Figure 6) is a community with 38 floating homes on the Willamette River, Portland, Oregon. The close proximity of downtown with pastoral setting of OYC is regarded as one of the best floating home village in the area.

In OYC, there is a floating house with 2 storeys and 212 square meters. That is ultra-low enegry house and the entire structure is made of glued laminated wood sections for swirling and curved design. This kind of construction not only makes versatile forms but also greatly reduces the overall amount of material used, and so is very light and easy to produce.

The window wall is only for taking in amazing river views and the glass allows the solar heat and light during the day while providing natural ventilation. With the materials prefabricated and transportation by boat, the home construction required minimal amounts of energy, and most importantly, did not disrupt the atmosphere of the floating home community. The house is integrating a beautiful, modern home into its surrounding environment.

In floating home community, residents enjoy the peaceful and comfortable atmosphere on water within the natural setting. They believe the best view is seeing only the natural elements such as sky, mountain & tress, grain field, and water without any artificial features. Connection to nature is likely to generate positive states of well-being and health. They enjoy sunrise and sunset with water and mountain background. There should be psychological sustainability among the residents and neighborhood.

The residents have great interesting in conserving the natural environment like wild birds and watershed vegetation, have to cooperate in managing the natural disaster like flooding and typhoon, have to cope with the fire and escape, and should negotiate the legal regulation with

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the city officers and get administrative/financial support from the City government. Solid social sustainability is essential and easy to be found in floating home community [10].

4. Sustainable Factors in Floating Architecture

Table 1. Applied Sustainable Factors by 3 Dimensons

Name of Building	Sustainable Factors			
	Environmental Dimension		Economic Dimension	Social Dimension
Common	- flood resilience - adaptation to water level change	- long-term usage	- relocatable	- solider security against crime - peaceful atmosphere
Floating Pavilion	- solar thermal collector & absorption - PCM	- natural ventilation - water reuse and treatment	- plan of relocation - 3 layer ETFE	- place-making for meeting & events - landmark
IBA Dock	- solar PV module - hydrothermal use	- thick insulation	- prefabrication & modular design	- community development
Autark Home	- solar PV module - bio-diesel generator	- self-sufficient system - thick insulation	- heat recovery system	- livability
Makoko Floating School	- solar PV module - use of local material	- natural ventilation - collecting rainwater	- reuse of plastic barrel	- social support - community resilience
Brockholes Visitor Center	- restoration of natural environment - biomass boiler	- water reuse - natural ventilation & external awning	- insulation made of recycled paper	- peaceful surrounding - social capital
Oregon Yacht Club	- conservation of environment	- low energy house	- prefabricated construction	- high sense of community

The applied sustainable factors in floating architecture by 3 dimensions can be summarized as follows (see Table 1);

- Environmental dimension: flood resiliencet and adaptation to water level change, renewable energy (solar thermal collector, solar PV module, hydrothermal, biomass boiler), bio-diesel generator, PCM, use of local material, restoration & conservation of natural environment.

- Both environmental & economic dimensions: long-term usage, water reuse & treatment, natural ventilation, external awning, collecting rainwater, thick insulation, self-sufficient system, low energy house

- Economic dimension: relocatable, 3 layer ETFE, prefabrication & modular design, heat recovery system, reuse of plastic barrel, insulation made of recycled paper, prefabricated construction.

- Social dimension: solider security against crime, peaceful atmosphere, place-making for meeting & events, landmark, community development, livability, social support, community resilience, social capital, high sense of community

5. Conclusion

As climate change like global warming advances, level of sea and river rises. Usable land in urban area becomes less and the price is rising due to continuous expanding development.

And people want to enjoy the activities on water rather than on land according the improved level of living. This paper aims to investigate the applications of sustainable factors in floating architectures and to suggest some reference ideas for new projects.

The applied sustainable factors in floating architecture by 3 dimensions can be summarized as follows; water resilience, renewable energy, PCM, local material, preservation of natural environment in environmental dimension; long-term usage, water reuse & treatment, natural ventilation, thick insulation, self-sufficient system in both environmental & economic dimensions; relocatable, 3 layer ETFE, prefabrication & modular design, heat recovery system, insulation made of recycled paper, prefabricated construction in economic dimension; solider security against crime, peaceful atmosphere, landmark, community development, livability, social support, community resilience, high sense of community in social dimension.

Floating architecture on water has been emerging as a sustainable alternative around the waterside region, and floating architecture can be regarded as one of the most sustainable building types if proper sustainable factors would be applied.

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Influence of affluence on sustainable housing: a contextual study of Mysore, India

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Abstract Summary*: This inter-disciplinary research draws understanding from the social-cultural and economic studies to define the values and aspirations of the middle class demographic and its implications on the sustainable housing. Shared spaces have traditionally played a key role in passive cooling strategies and the maintenance of socially sustainable communities. Changes in social conditions, practices and lifestyle can be traced by the way they identify, demarcate and celebrate their boundaries. This research points to the importance of the external boundary of the site and the edge of buildings in terms of aligning meaningful sustainable design strategies with the concerns and aspirations of the emergent middle-class. Generating 3D models and applying an environmental design method, possible options for these external boundary conditions are tested, which are validated by the stakeholders during the fieldwork. This research provides new-insight into the way sustainability can be understood with qualitative values that are complemented by quantitative measurements.*

Sustainable Housing, Indian Middleclass, Developing countries, 3D Model simulation

Background study

It is important to understand housing as social and cultural phenomena that can allow insights in the effective formulation of localised and relevant low carbon housing strategies. Although strategies such as converge and contract [1] seek to accommodate developing countries' valid aspirations to achieve higher levels of prosperity, there is still an imperative to reduce carbon emissions within India. Whilst a low carbon society for developed nations can be defined as "inventing low carbon technology and reducing carbon dioxide emission by the middle of 20th century" [2]; for developing nations, achievement of low carbon communities must go hand in hand with achieving wider development goals. Further, while acknowledging the role of technology, emphasis has to be given to the importance of lifestyle and social change [2]. The complex and multifaceted society of India is interwoven with caste, religion and regional disparities, where newfound economic status and affluence in middle-class segments has a critical impact in the process of sustainable development.

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The residential sector in the construction industry accounts for 22% of global energy consumption [3]. In case of India, about 17% of emissions originate from construction activities of which 60% can be attributed to the housing sector [4]. In India with new build reflecting greater income and mobility amongst the population, it would be simplistic to characterise a growing middle class as being exclusively materialistic where social and cultural conditions unique to India have the opportunity to marry prosperity, property and low environmental impact.

The provision of housing in India has traditionally been less related to income and wealth. It is proposed to explore this theme through the example of the city of Mysore, India. It is a useful exemplar in that it has a history that directly influenced environmental response in the built environment [5]. Shared facilities (including party walls), the efficient use of semi-open outdoor spaces for much of the day, and the effective use of multi-purpose areas all facilitated a compact building footprint. Using locally available material within a climatically responsive layout and construction would today be regarded as a good example of efficient sustainable development [6]. Plot ratios are dense compared to more diffuse contemporary layouts with less environmental impact because of a more efficient land use. Comparisons in Mysore of typical Agrahara settlements with contemporary middle-income settlements indicate an increased dwelling footprint. Cartographic measurements of representative land parcels indicate that for a contemporary dwelling, 50% more plot area is required compared to more traditional Agrahara typologies [7, 8].

It is suggested that the Jagali neighbourhood embodies a sense of the communal that reflects the values of the Nehru consensus middle class. Modern typologies mirror the ascendance of the individual over community where often, competing needs for privacy and display produce buildings that are inefficient in their use of land and building materials, with little consideration given to passive methods of environmental mediation.

Methodology: Models and simulation analysis

This paper draws observations and conclusions of the earlier research and fieldwork to identify the needs and wants of middle class homeowners [7, 9-11]. Structured interviews and surveys clearly indicated the concerns for security and notions of protecting one’s boundary, coupled with the need for privacy, and the use of form and façade to provide visual cues in expressing wealth and aspiration [7, 8]. The understanding of the fieldwork is triangulated with literature studies and the outcomes related to boundary conditions are used to produce different computer models, representing alternatives for major elements, a sustainability agenda and middle class aspirations. Feedback from architect, builder, and homeowner is used to define these models that are then related to sustainable values.

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The fieldwork was combined with intensive literature reviews of both contemporary Indian building typologies [12-15] and research on boundary, threshold and border that help explain contemporary preoccupations with security and defensible space [16-20]. From this a series of four test models were generated for study in respect to both predictive quantitative performance and as a basis for revisiting the fieldwork. The models were organised to test housing market stakeholders' responses to a range of sustainable criteria. At one extent a traditional bioclimatic solution that reflects past models of communal living and at the other extent, a model representative of current private sector middle class housing were constructed. A further two models between these extremes were designed primarily to get a finer understanding of the exact levels of privacy and social interaction that might be embraced by potential stakeholders (Figure 1).

The focus of this research is to access the implication of varied boundary condition in terms of change in energy consumption and resultant carbon emission. For the simulation purpose, only these boundary conditions of different typologies are altered while providing input in Integrated Environmental Solutions (IES). The models were generated with similar configuration in terms of built up area, number of rooms, size of the plot and provision for minimum light and ventilation. To focus the research more on the boundary conditions, all other components such as constructional systems and spatial planning were kept as constants. An advanced simulation package, IES, was used in this research. IES uses climatic data and supports a range of analytical tools for lighting, thermal comfort and resultant energy consumption and carbon emission. To predict energy consumption and carbon emissions, longitude and latitude were specified for Mysore using climate data from Bangalore, the nearest city to the study area.

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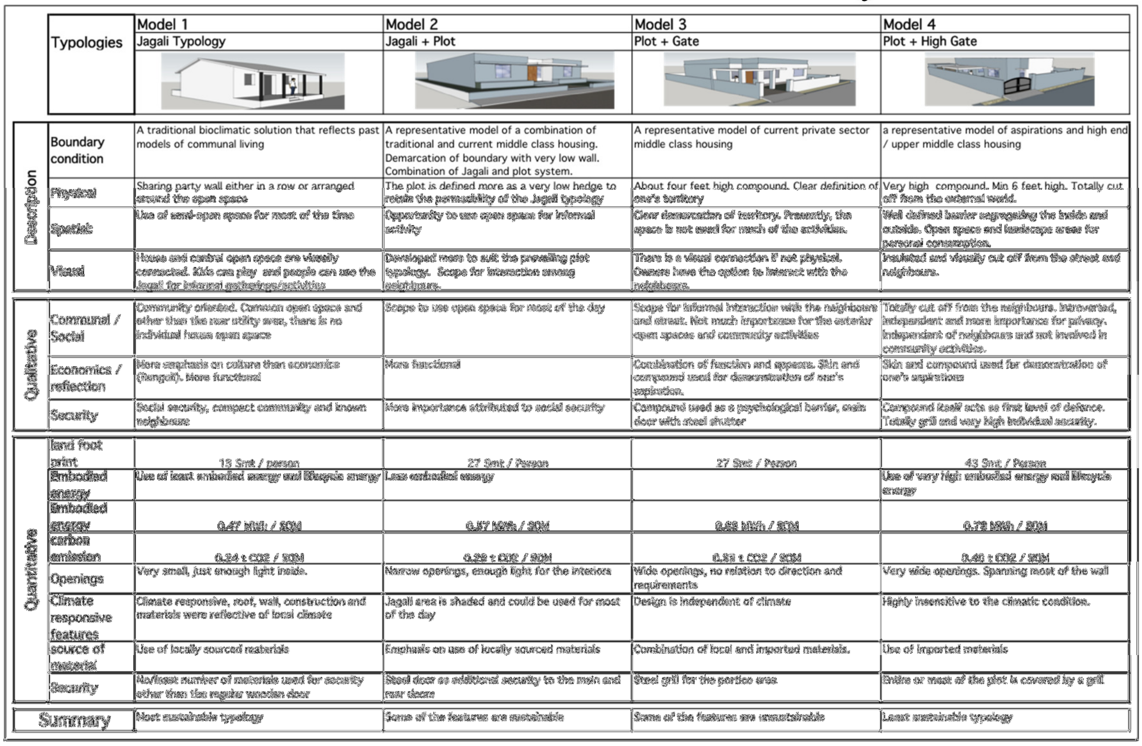

		Model 1	Model 2	Model 3	Model 4
	Typologies	Jagali Typology	Jagali + Plot	Plot + Gate	Plot + High Gate
Description	Boundary condition	A traditional bioclimatic solution that reflects past models of communal living	A representative model of a combination of traditional and current middle class housing. Demarcation of boundary with very low wall. Combination of Jagali and plot system.	A representative model of current private sector middle class housing	a representative model of aspirations and high end / upper middle class housing
	Physical	Sharing party wall either in a row or arranged around the open space	The plot is defined more as a very low hedge to retain the permeability of the Jagali typology	About four feet high compound. Clear definition of one's territory	Very high compound. Min 6 feet high. Totally cut off from the external world.
	Spatial	Use of semi-open space for most of the time	Opportunity to use open space for informal activity	Clear demarcation of territory. Presently, the space is not used for much of the activities.	Well defined barrier segregating the inside and outside. Open space and landscape areas for personal consumption.
	Visual	House and central open space are visually connected. Kids can play and people can use the Jagali for informal gatherings/activities	Developed more to suit the prevailing plot typology. Scope for interaction among neighbours.	There is a visual connection if not physical. Owners have the option to interact with the neighbours.	Insulated and visually cut off from the street and neighbours.
Qualitative	Communal / Social	Community oriented. Common open space and other than the rear utility area, there is no individual house open space	Scope to use open space for most of the day	Scope for informal interaction with the neighbours and street. Not much importance for the exterior open spaces and community activities	Totally cut off from the neighbours. Introverted, independent and more importance for privacy. Independent of neighbours and not involved in community activities.
	Economics / reflection	More emphasis on culture than economics (Rangoli). More functional	More functional	Combination of function and appeara. Skin and compound used for demonstration of one's aspiration.	Skin and compound used for demonstration of one's aspirations
	Security	Social security, compact community and known neighbours	More importance attributed to social security	Compound used as a psychological barrier, main door with steel shutter	Compound itself acts as first level of defence. Totally grill and very high individual security.
Quantitative	land foot print	13 Smt / person	27 Smt / Person	27 Smt / Person	43 Smt / Person
	Embodied energy	Use of least embodied energy and lifecycle energy	Less embodied energy		Use of very high embodied energy and lifecycle energy
	Embodied energy	0.47 MWh / SQM	0.57 MWh / SQM	0.68 MWh / SQM	0.72 MWh / SQM
	carbon emission	0.24 t CO2 / SQM	0.29 t CO2 / SQM	0.33 t CO2 / SQM	0.40 t CO2 / SQM
	Openings	Very small, just enough light inside.	Narrow openings, enough light for the interiors	Wide openings, no relation to direction and requirements	Very wide openings. Spanning most of the wall
	Climate responsive features	Climate responsive, roof, wall, construction and materials were reflective of local climate	Jagali area is shaded and could be used for most of the day	Design is independent of climate	Highly insensitive to the climatic condition.
	source of material	Use of locally sourced materials	Emphasis on use of locally sourced materials	Combination of local and imported materials.	Use of imported materials
	Security	No/least number of materials used for security other than the regular wooden door	Steel door as additional security to the main and rear doors	Steel grill for the portico area	Entire or most of the plot is covered by a grill
Summary		Most sustainable typology	Some of the features are sustainable	Some of the features are unsustainable	Least sustainable typology

Figure 1. Analysis of different model typologies

The focus of this research is to access the implication of varied boundary condition in terms of change in energy consumption and resultant carbon emission. For the simulation purpose, only these boundary conditions of different typologies are altered while providing input in IES. The models were generated with similar configuration in terms of built up area, number of rooms, size of the plot and provision for minimum light and ventilation. To focus the research more on the boundary conditions, all other components such as constructional systems and spatial planning were kept as constants.

IES allows altering the input of each typology while retaining some of the features as constant across all typologies. Further, it allows comparison of specific parameter across typologies during output. For instance we can run the models to simulate only the conductive heat gain, where the internal temperature rise is due only to heat gain by conduction. Similarly, the energy consumption due to cooling load, resultant of bringing down the internal temperature to set comfort condition is assessed (Figure 2 and 3).

A key finding is one of increased energy consumption in the high compound typology (model 4) representing the aspirational model. It uses nearly 65% more energy than model 1 (the Jagali typology). Similarly, there are differences in the performance of other models; for

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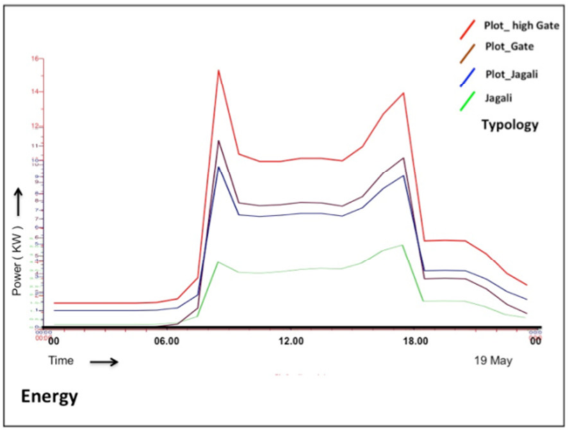
instance, in the case of energy consumption, the high compound typology (model 4) requires nearly 300% of more cooling load compared to a Jagali house typology (model 1). And even this will increase the conduction gain by nearly 90%. The simulation output demonstrates that changed boundary conditions have implications for energy consumption and resultant carbon emission. They also validate the hypothesis while developing models that explore different boundary conditions. It also clearly points to a direct relation between peoples' changed preferences and aspirations and their implications for energy consumption and carbon emission. The outcome clearly indicates higher conduction gain, cooling load, energy consumption and resultant carbon emission in plot and high gate typologies and consistently lowest energy consumption and carbon emission in the Jagali typology.



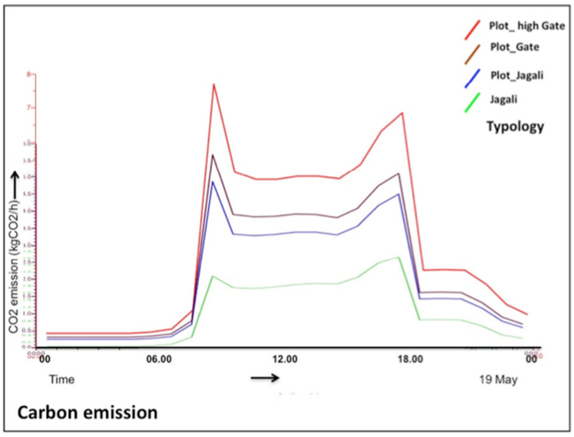


Figure 2. IES simulation: Energy consumption *Figure 3. IES simulation: Carbon emission*

Fieldwork

The main objective of achieving sustainable strategies within the existing middle class paradigm is achieved by contextualising the broad term of sustainability to Mysore condition on one hand and reflecting the acceptability of middle class homeowners' preferences and acceptability on the other. The models prepared and simulations carried out reflect the local sustainability agenda and different levels of sustainability with specific reference to boundary condition. Further fieldwork looked the aspirations of the middle class people and their willingness to align towards more sustainable features. The models were tested with homeowners by semi-structured interview and with key stakeholders in the design and procurement process. To analyse the issues reflected in transition spaces, elements representing middle class aspirations and the sustainability agenda were identified, namely: Volume, Entrance, Opening, Security, Interaction and Skin [9, 11].

To elicit preferences and log the choices of people, architects and builders, a 'multi sorting task' methodology was followed. As Groat [21] has argued, it is possible for the participants either to sort representations of buildings they had experienced directly or pictures that

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functioned as simulations of the real environments. The models are deconstructed to highlight the element investigated and the complete 3D study models are not shown to the participants to avoid distraction. This technique is very helpful in this type of study as respondents are asked to place the cards from most acceptable to least acceptable. This multi sorting process was validated through a semi-structured interview. Apart from noting their preferences, the process was recorded and interviewees were informally questioned as to their decisions.

Fieldwork analysis, Discussion

The outcome of this fieldwork addresses issues including social and cultural values and perception of key stakeholders towards middle-income sustainable housing. The study can be broadly addressed at two levels; firstly, it deconstructs how various stakeholders perceive boundary and threshold in housing. The interview and survey assesses the choices and preference of a particular topology based on issues like, security, material, interaction etc. their choice of most preferred and least preferred are further triangulated with the discussion during the process about the rationale behind their choices and why they think their choice is appropriate.

At second level, the study analyses how the peoples' perception changes with awareness. The house owners are asked first to prioritise their preferences. Later after being given information on issues relating to climate change and sustainable housing, they are asked to again place their preferences. Feedback from stakeholders; architects, builders, contractors and home owners are analysed for each element identified namely; Volume, Entrance, Opening, Security, Interaction and Materials. Though there is a clear departure from the sustainable boundary condition, the outcome clearly reflects varied preferences among different elements identified. To summaries the field work results; two representative outcomes, Volume and Opening, are discussed below.

Volume: In the case of different Volume options, stakeholders strongly feel that the prevailing plot typology is most desirable followed by high gate typology preferred by more than 65% of homeowners. The most sustainable, Jagali typology is the least preferred option. Their strong preferences are evident while analysing their preferences after providing the information regarding sustainable concerns. Homeowners' revised preferences clearly reflect marginal decrease in the high gate typology, which is reflective of many unsustainable features and less than 10 % increase in the preferences for Jagali typology. Similar trend can be observed among other elements like, Entrance, and Security.

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Opening: In the case of different opening options, stakeholders are divided among the wide, small and inward openings. Less than 10% of homeowners prefer opening towards shared areas. According to one architect, changed social network and priorities makes this a least feasible typology (respondent no.76, interviewed on 09 March 2011). The concern and acceptability of the homeowners are evident, while their preference for the wide openings are reduced to less than 5%, their preference for small opening is increased by 20%. Similar trends can be found in case of Material choices as well.

Choices and preferences clearly represent the area in which we can expect people to support and adapt to sustainable features. The feedback can be classified in to three types. First the elements which people are ready to change their preferences for the cause of sustainability, in this we can easily find the materials, skin and openings as two aspects which people are ready to align towards a sustainable agenda. There are certain elements for which they do not have very strong preferences and to some extent are ready to align themselves. In this case people might consider some adjustment but are not ready to forthrightly support a sustainability agenda. However when it comes to issues like security; people are not ready to compromise and would not be interested in sustainability issues and would not compromise on their perception of what is safe and secured for them.

This study has been very useful in disentangling one area, the boundary condition and look at each element separately so as to identify people's choices and preferences resulting in the housing typology and hence resultant sustainable concerns rather than broadly summing up the boundary conditions as unsustainable in present context.

This study is also helpful in identifying the areas and elements where it is easier to achieve higher sustainable goals compared to areas where there will be higher resistance to change. Revising the model to suit both peoples' choices and sustainable agenda further tests this. Peoples' choices and preferences, collected by social methods, are fed into the IES simulation model to analyse the difference in the process of sustainable housing. To test this one model is altered to have optimum size windows which people would be ready to align with to achieve more sustainable housing.

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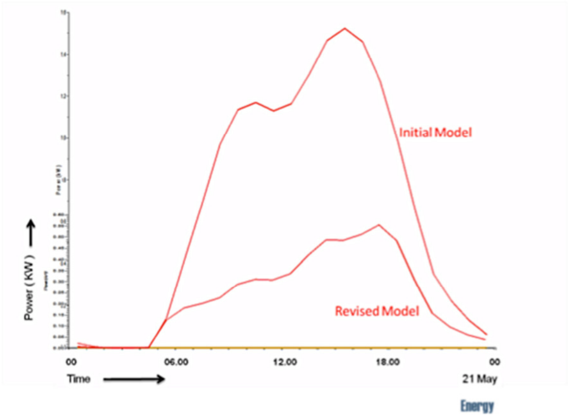

Figure 4. Post-field work: Energy consumption

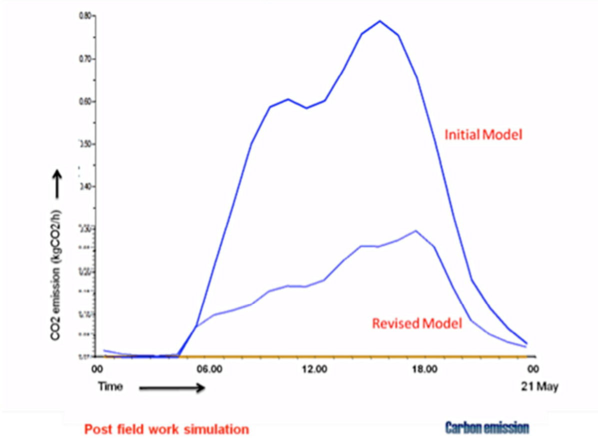

Figure 5. Post-field work: Carbon emission

The new IES simulation chart clearly shows a drop in the energy consumption of 40% (Figure 4). The changed window parameter has also reduced the carbon emission by 40% (Figure 5). The results clearly show that, by changing the elements which people are ready to alter, we can reduce carbon emission by a fifth. This is significant because it is useful to know where we can really target and reduce emissions.

Conclusion

This research demonstrates that homeowner's attitude towards housing elements depends on the specific issue and individual perceptions. Furthermore, their preferences will not only depend on the individual, but are also influenced by the building elements. For instance, middle class homeowners strongly prefer the high gate plot typology and would not like the 'Jagali' typology. The post-fieldwork analysis clearly demonstrates that in spite of a clear move away from sustainable living, the values of people can be recognised as being more than 40% ready to change their life style to align themselves towards more sustainable housing.

Researchers have proved that the homeowners of naturally ventilated buildings will accept and feel comfortable in a wide range of weather conditions [22]. The weather condition of Mysore facilitates passive ventilation and cooling strategies for most of the year except during the extreme summer of April and May. This research points to the limits of adaptive comfort as homeowners' affluence and aspirations have made them more sensitive to temperature variations and energy intensive mechanical devices accessible to manage their micro-climate. Improvements in the standard of living, a sensitivity and desire to achieve desired comfort conditions in the internal spaces have encouraged middle class owners to invest in these mechanical devices. Furthermore, the interview feedback suggests that most of these mechanical devices are installed to display homeowners' wealth.

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The study using survey field work and model simulations has highlighted the relatively recent shift in attitudes and cultural values relating to housing; from an inherently sustainable approach which valued shared spaces, local materials and communal activities, to one which reflects a move towards a twentieth century western approach; of individualism, nuclear families and consumer driven values. The study also clearly demonstrates that there are elements like materials and openings, which people are willing to align themselves with and that there are elements like security, which they would not compromise. Their immediate concerns would be of greater importance than the greater issues of carbon emission and sustainable housing.

India has identified Housing as one of the eight national missions to reduce carbon emission as part of its commitment to reduce the vulnerability of the people to the impacts of climate change [23], this bottom-up approach to identify the sustainable strategies acknowledging people's needs and aspirations should be a useful contribution to achieving carbon reduction and sustainable housing.

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Session 136:

Where should energy renovation reach up to? (IV)

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Sustainable Urban Development European Network (SUDEN), France

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Towards determining daylighting design parameters in student dorm rooms-the South Eastern Europe case study

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Abstract: *Daylighting parameters were investigated in the case study of an existing multistory student housing in Serbia. The daylighting conditions within student quarters were analyzed by using measurements, simulation and qualitative survey among the dormitory dwellers. A comparison was made and the results were classified at different orientations. The authors suggest the differentiation of the orientation requirements regarding daylight and sunlight in the regional context. Since direct sunlight was seen as a favorable component within the dormitories, the future studies should be engaged in determining the ratio between excess daylight and minimum daylight a room should receive. The conclusions from the approach presented in this paper point out to the savings in the context of energy efficiency especially if more funds and time were invested in satisfying as much as possible passive design features in the building, instead of post-development refurbishments.*

Daylight, learning environment, sunlight, orientation, user´s opinions, SEE, energy efficiency

Introduction

The following research paper consists parts of the recently published paper listed in the references section (the latest one) and comprises further recommendations for research in the area of daylighting and buildings within local particularities and specific climates as additional material to the original paper.

The research of daylighting qualities and orientation of the facades of Serbian buildings was motivated by the observation of the authors that when building a dormitory in the Serbian practice, orientation and passive design do not seem to play any role in the design stage. Yet, various studies that have examined day lighting have suggested the benefits within a climate specific passive design [1,2] and some of them even suggested a thorough study in the regions not belonging to the highly developed northern European countries, for which a considerable amount of research in the field already exists [3]. By determining the qualities of daylighting within the case study dwelling building, and using a combined analysis with the dwellers' feedback, this papers aims at better consideration of orientation for the utilization of daylighting in the region of Southeastern Europe (reffered to as SEE further in the text).

Due to an increase of temperature and more frequent appearance of dry cloudless weather in Serbian cities, especially in late spring and summer, the problems of overexposure to direct sunlight and thermal discomfort may become more acute and therefore the reconsideration of the current design principles of facades is necessary in this sense. Finally, visual

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requirements within the dwelling spaces have to be fully satisfied. That is why it is important to give the designers a feedback on visual comfort satisfaction among the dwellers and finally determine the best relation between these two groups of parameters.

The use of daylight is considered to be an effective measure to reduce the artificial lighting requirements of public buildings [5, 6, 7]. Additionally, achieving large reductions in energy consumptions for the built environment professionals and industry today is one of the biggest and most urgent challenges [8] and its importance in terms of lighting in the Southeastern Europe had been already suggested by Kostic and Djokic [9] among others. Since student dormitories in Serbia are mostly state funded buildings and take significant part in the total share of University infrastructure costs, rational exploitation of energy is of great importance for attaining savings in the state funds. Moreover, it is considered that school children, students, and people engaged in visually demanding activities are the groups for whom good daylight conditions are of utmost importance. It has been concluded that exposure to natural lighting has effects on increased presence of students at lectures, better results and marks, reduction of fatigue, and general improvement of mental and physical health [10]. It is of high importance to properly evaluate visual comfort in dorms after they had been completed and investigate their performance. The incongruity between current daylighting standards and real life daylight performance suggests modifications in the daylight evaluation are necessary.

Work methods

The daylight conditions were simulated in the rooms of a student dormitory in Nis, Serbia presented in the figures, and both the quantitative analysis (the survey) of the students' opinions and the qualitative one (the interview) were performed among the dorm population. The snap shot of daylighting conditions made by using on-site measurements served as an addition to the annual general data sets in the sense that it gives data on the actual daylight values within the work and living spaces during one complete day a student spends in the dormitory. It also presents a check of viability of the synthesized annual simulation data at smaller time instance such as a day. The analyzed student hostel, has a standardized floor layout (presented in the figure 1), which is rotated 33°counter- clockwise in respect to the N-S axis. Next to the building itself, there are no structures which would either obstruct illuminance or contribute to it via reflection, so this was ignored in the analysis.

Fig 1 Student dormitory layout plan, rooms with the measurement points and appearance of one of the rooms

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Simulation methods and results

In order to determine the daylight conditions at the annual level, the simulation using the DAYSIM 3.0 software was initiated, which takes into consideration the climate file and three-dimensional object file in order to obtain the parameters, such as the daylight factor (DF) at the annual level for individual rooms of various orientations, daylight autonomy (DA), as well as useful daylight illuminance (UDI). The rooms analyzed in the simulation were K2(NW), B1(NE), D1(SE) and A1(SW). Fig. 2 shows simulation results of DF and DA for four differently oriented rooms, on the points distributed in the particular room moving in zig-zag starting from the closest node to the window (point 1). Both DF and DA is decreasing as the points are selected from window towards corridor. It is worth to note that only NW oriented K2 room has all points with DA over 50%. Within all four orientations, the first three sensor points closest to the windows, which correspond to the work places, were determined to have daylight factor of more than 4%, which is more than it is prescribed by daylighting standards such as EN 12464-1, BREEAM or LEED. Judging by the UDI set of parameter values, there is sufficient daylight within the observed rooms.

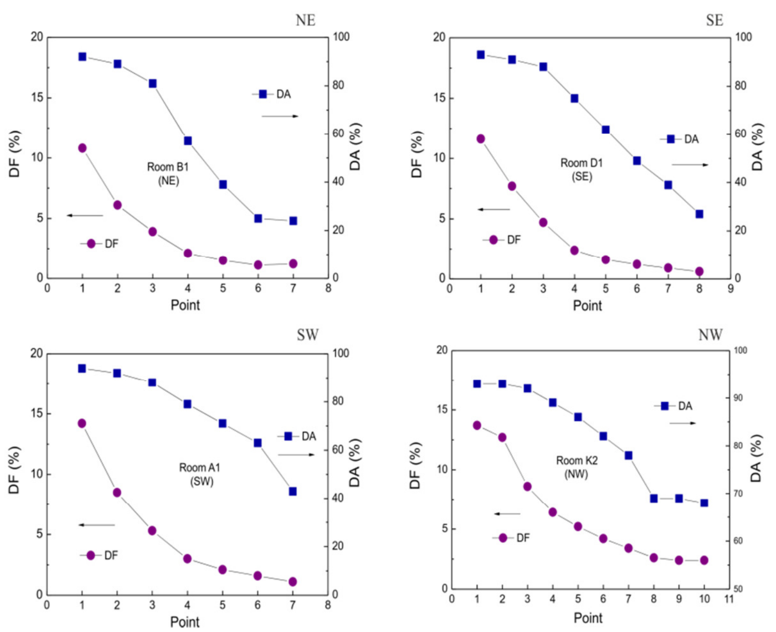

Fig 2 Some of the simulation results

For example, NW and SW orientations showed the DA values of 50% or more in almost all analyzed points. A similar situation of the DA values of 50% or higher can be observed in the NE and SE orientations although within a fewer number of points in comparison to the NW and SW orientations.

The DA parameter seems also viable since the survey results indicate that the majority of the students (69-90% depending on the date and specific orientation) were generally satisfied with the daylight in the rooms. Judging by the outcomes of the UDI parameter analysis, the UDI achieved values are present within 80% of all simulated points at the northern orientations (NW and NE). In the southern ones, these values were present with 50% or less of all values. According to this, the northern orientations are expected to have more suitable daylighting values in general.

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Measurement methods and results

The measurement of the horizontal illuminance was done and a corresponding daylight factor was calculated in four different types of orientation. The measuring was performed in autumn (on October 5th and October 27th) having mostly sunny (October 5th) and mostly cloudy skies (October 27th), for clear glassing area – without shadings and with shadings. The measurement time choice factor corresponded to the periods in the year when students most intensively learn and prepare their exams. Also, the measurement time was within the average yearly values of insolation for this location. The shades used correspond to the actual existing inventory of the dorm rooms. The measurements were repeated at - 9:00 a.m, 12:00 p.m, 3:00 p.m, and 6:00 p.m. (the measurement positions can be seen on fig. 1). Figure 3 shows the measured values of illuminance with and without the shades versus the time for four rooms with different spatial orientation. The DF values for the first two points (students' workspace) and the central point of the room (third point) are higher than 3%, which is above the minimum mentioned in the previous chapters.

The fourth point (the zone for rest and occasional visual activities of the students) has the DF values that are lower than the minimal 2% in all room orientations, and is therefore the detail that could be improved in the future designs.

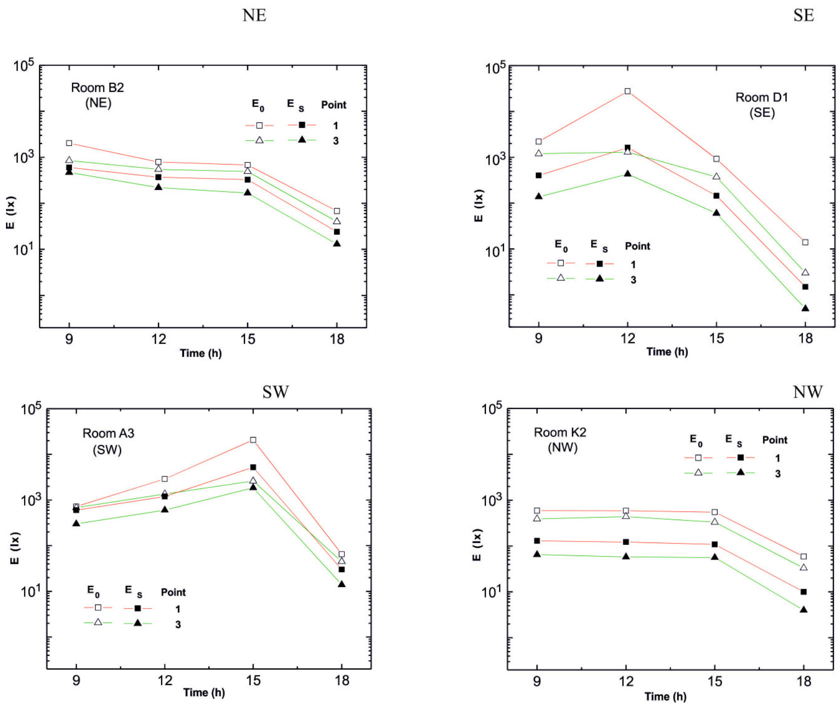

Fig 3 Some of the measurement results

Questionnaire and interview methods and results

The questionnaire and additional interviews were carried out with the students inhabiting differently oriented rooms. The survey was done among the students of various ages and gender and of diverse education profiles and faculties. In the survey, daylight was considered to be *very important* for living and working in a room by a large number of examinees (50% in the spring survey and 69% of the examinees in the autumn one). The answer *important* was given by 33% in the spring survey and 24% in the autumn one. The percentage of the students who found it *less important*, *almost unimportant*, and *totally unimportant* was less than 15% in all room orientations. The residents of the dorm were to a great extent satisfied with the natural light in rooms. Most of the examinees (45% in the spring survey and 71% in the autumn survey) were *satisfied*, while there were 7-13% of those who were either *dissatisfied* or *indifferent*. In the spring survey, 28% of the examinees were *very satisfied*, whereas this percentage was lower in the autumn survey, 9%. Only 8% of the examinees were *totally dissatisfied* by the amount of illuminance in the spring series, while in the autumn survey, the percentage was negligible. Within the qualitative interview method, in order to examine the survey results in detail, 12 residents were interviewed – three from each of the four existing orientations. The questions asked in the fifteen-minute interviews clarified their subjective reasons for satisfaction or dissatisfaction by daylight. The questions referred to the quantity of lighting in their rooms, the time of its occurrence, and how they relate the quality of lighting to thermal comfort. The general conclusions that can be drawn from the results of the interviews are the following:

1. The majority of examinees of southerly orientated rooms in the interview faced a problem of too high intensity of sunlighting in the summer months, which they could not resolve by themselves. Thermal discomfort, which is related to direct insolation, was particularly present in the southwest orientation. On the other hand, the residents of this orientation were the most satisfied by the lighting in their room in comparison to the students from differently orientated rooms. According to the survey results, the rooms of this orientation had the fewest hours without daylight.

2. For the examinees with the rooms of northern orientations, the lack of daylight in certain situations did not present a big problem, since they could learn in either the drawing or reading room. Lack of illuminance in different parts of the year was the biggest problem for the northeast oriented rooms, particularly in autumn. The students living in these rooms experienced insufficient illuminance in autumn, which they regarded as unfavorable for work. Furthermore, since this was the period without central heating, the examinees' impression of bad illuminance was even further intensified due to inadequate heating conditions. The NW orientated rooms showed satisfactory results and fewest complains within the survey about daylighting conditions, even though there was no direct sun lighting most of the year. On the other hand, these rooms were subjectively evaluated as the coldest rooms in the dorms. In the summer season, both northerly orientations were the most favorable in terms of illuminance, while in spring and autumn the southeast ones were almost ideal in terms of daylighting.

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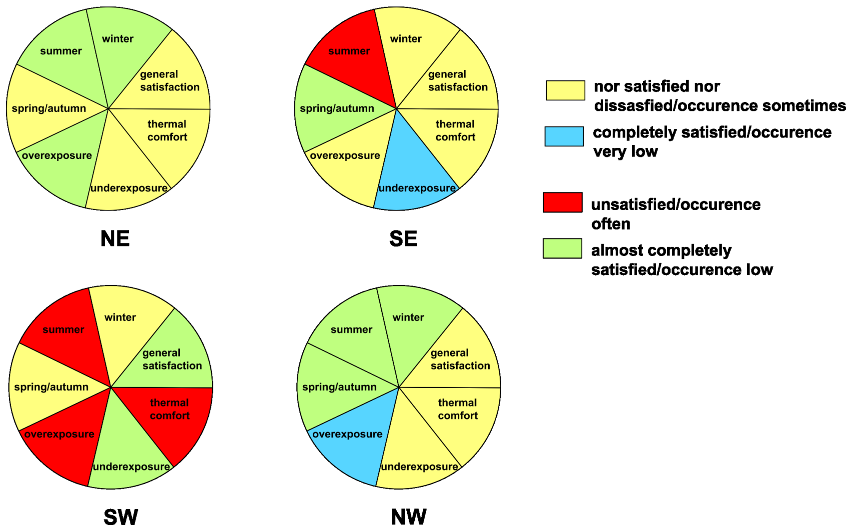

Fig 4 Some of the survey results

3. Although they were generally satisfied with the daylight conditions in the dormitory, the examinees from NE, SE and SW oriented rooms pointed out occasional lack of daylight and problems with overcast sky conditions as being problematic in certain parts of the year. The lack of daylight is caused also by the usage of protective measures (undertaken by the students themselves) from excessive light.

4. When asked to compare rooms of different orientations for daylight (several examinees lived in two or more differently oriented rooms in the same dorm), the southeast rooms were preferred to both northern and southwestern orientations. One reason behind these opinions could be found in the favorable amount of sunlight in winter and autumn, which northern orientations lacked. Another one was acceptable quantities of unwanted sunlight in summer, which the students regarded as a drawback in southwest orientated rooms.

When analyzing in detail the interview results available in figure 4, SE and NW oriented rooms were almost completely satisfactory in terms of underexposure or overexposure to daylight. On the other hand, SW oriented rooms were neither satisfactory nor unsatisfactory. Finally, the results of NE orientations were somewhere in between on the scale.

Relation between measurement and simulation results and the survey results – novelty of the study

It was noticed that higher percentage of UDI exceeded values were present at those orientations whose dwellers expressed biggest concerns with overexposure to daylight and sunlight. This indicates that the results obtained by simulating the UDI are fully consistent with the students' observations in the interviews. However, in the considered case, the result of the interviews which show the preference of the students to live in the SE and SW oriented rooms (where the highest UDI-exceeded values are observed), indicates that overexposure to daylight in some parts of the room does not necessarily mean that this space is not entirely suitable for dwelling.

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Recommendations of the paper

The point that further undermines the importance of even distributed daylighting in determining daylighting qualities of the space is the dwellers´responces that show preferences to southern orientations regardless of the fact that they are more frequently exposed to direct sun [11]. In the South-east European context, this may be connected to climate and cultural particularities of the region. The next step of the study would be to implement the location specific conclusions into the real time design situations and standards. It should be mentioned that the approach presented here could be implemented to other locations that share the similar conditions, with modification and analysis of the dweller´s feedbacks in order to give more accurate conclusions on the topic.

Since direct sunlight was prefered among the dwellers in the case study, the future studies should be engaged in determining the ratio between maximum and minimum daylight and sunlight illuminance values a room should receive.The critical conditions such as overcast skies must be seriously investigated, since they were directly connected to the opinions of not being satisfied with the lighting and thermal comfort situations among the dwellers. Also, the systems shoud be thought over, that enhance the daylight or/and subjective impression of the presence of direct sunlight within inconviently illuminated room spaces. In this paper, it has been proven that there is a relation between daylight parameters and thermal comfort. It is the opinion of the authors that finding the most favourable designs based on the typical climate conditions, location particularities and satisfying minimal requirement for the above given parameters may be more satisfactory and end-up in saving a lot of future refurbishment and inventory costs. That is why more funds and time should be invested in research of the possible passive and pre-design features of the building process. Especially in the traditionally unstable economic situation in the SEE and present uncertanty of available energy resources for the future.

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Innovative technology versus tradition in energy efficient renovation

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Abstract. *Energy efficient residential renovation often does not match the calculated results. After considering the rebound effect the explanation tends to be: unpredicted user behaviour. The needs and user patterns in housing are diverse and may differ from input in calculation methods. Also, many technical services are not used according to plans and for obvious reasons. The conflict between theory and practice are compared for:*
-Manual or automatic inlet and exhaust and heat recovery ventilation;
-Local heating versus central heating;
-Manual or clock controlled thermostats and innovative home energy management.
Triple glazing is compared with double-glazing as an example of popular belief against facts. Robust systems that provide direct feedback and allow much flexibility during different seasons and during day and night are preferred. The first priority of renovation is to improve the envelope and the ventilation system.

Key words. **Energy efficiency, residential renovation, user behaviour, climate control**

Introduction

The energy policy is to save 20% energy in the building sector in 2020, compared to 1990, and receives wide support from social housing associations. During the past period homeowners in The Netherlands have picked “low hanging fruit”. Practical new goals were chosen, for instance two energy-label jumps for the housing stock or from label E/F to B in retrofits. Selling part of the low-energy stock also increases the overall energy performance. A number of forerunners have adopted near-zero-energy renovation, using the capitalised energy cost reduction and the expected maintenance cost reduction for investments in zero-energy performance. By prolonging the life expectancy with 40 – 50 years the return on investment increases and plans become feasible. Forerunners are found in slow housing markets, where high quality is needed to be competitive. Energy Leap, Energy Momentum, Smart & Fast and Beem-Up (Building Energy Efficiency for Massive market Uptake) are among the creative slogans used to invite housing managers and construction companies to innovate. The majority of housing associations have problems with financing the renovation and the quantity of low-energy renovated dwellings is still low.

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The notion of practical energy savings instead of label jumps seems to disappear. Using the actual energy data before and after the renovation is an "innovative" approach. The Dutch tenant association Woonbond promotes the total cost of living guarantee that is based on real consumption patterns and that requires transparency about actual savings, but housing associations are reluctant to follow this recommendation. The push to reach energy goals seduces home-owners to follow trends that are politically correct but not practical. The PHPP (Passive House Planning Package) and TRNSYS are reliable calculation tools, but the simpler EPN (Dutch energy performance of buildings tool) is accepted for stock policy choices. Besides the discrepancy between input parameters and practical evidence, widespread failures in execution quality and unrealistic claims about the energy effect of products can cause discrepancy with field practice [3].

Majcen and Itard [1] [2] [3] found that a better energy performance coefficient is followed by lower energy consumption, but not to the same extent. Figure 1 shows the discrepancy. For low energy efficient dwellings (label E-G) the calculated consumption is too high. For dwellings with good energy performance (label A and B the actual energy consumption is higher than calculated, which also means that promised energy savings are not reached.

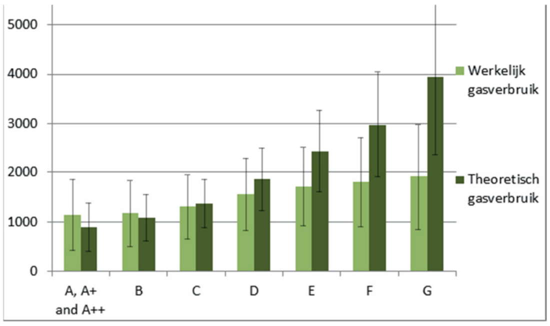

Figure 1. Actual (light bar) versus calculated (dark bar) energy consumption in natural gas per dwelling per year, from Majcen D. (2013), TU Delft

Housing associations normally ask rent increase for label jumps from D/E/F to B. Many tenants accept no more than 50% of what is calculated. Do they know better than experts what the practical effects will be?

Objective

The objective is to understand the reasons for the discrepancy between calculated and practical results of energy saving measures. The objective comes from the Beem-Up project, where partners develop and improve energy efficient renovation strategies in three pilot projects, namely Cotentin Falguière in Paris (78 apartments), Van der Lelijstraat in Delft (108 apartments/semi detached houses) and Brogården in Alingsås (300 apartments). The project goal is 75% reduction in heating energy demand through renovation. The project in Brogården is a passive house renovation with extreme heat demand reduction through insulation, sealing and heat recovery ventilation, but with little interest in user behaviour or individual heat metering, because the consumption is considered too low for that.

In Delft the focus is on a basic "free" package for insulation of the envelope (except floor insulation) and relies much on free selective measures that tenants can choose to further increase the energy performance: floor insulation, central heating with highly efficient heating/hot water source, solar domestic hot water system and an intelligent home energy management system.

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The multi-storey apartment block in Paris shows a great improvement in installations for heating and domestic hot water and includes a home energy management system integrated in the videophone-door answering service. All have 75% reduction of heating demand [4]. Final data on practical energy consumption is not available, because construction work is still ongoing. However, the results so far deserve a discussion on further steps toward low-energy renovation.

Figure 2 (upper left): the street fcade of the project in Paris, before renovation

Figure 3 (ower left): project in Alingsås

Figure 4 and 5. project in Delft before (l) and after renovation ®

Figure 6: project in Alingsås after renovation

Method

The focus is user oriented. Insight in energy related behaviour and in the effect of the renovation comes from interviewing the tenants. Energy using installations and household appliances are the starting point for discussions with the users about their perceptions and behaviour. For that reason a survey and statistical analysis is abandoned and the open-interview method was chosen. In different projects (Green Solar Cities and a program of the Passive House Platform in Belgium) users of low-energy and passive houses were interviewed as well [5]. Listening to the tenant's stories with an open mind and confronting the energy consumption with different energy concepts results in a critical review.

Results

General reasons for he difference between calculated and practical energy consumption are:
-Household size and age causes occupancy periods and temperatures different from reference;
-Too high heat losses to neighbouring apartments;
-Tenants accept a lower comfort: non-heated bedrooms, warm clothing when cold outside;
-Technical installations are not used as predicted, because of noise or draught.

The energy claims of providers of new applications are a reduction of the energy performance coefficient (the Dutch EPC) between 0,1-0,23. It means that for instance heat recovery ventilation can reduce the EPC from 6,23 to 6.0 and then the design meets the building code. The EPC-tool includes tested applications. Non-registered innovative products can be accepted on the basis of a “certificate of equivalence”. Many of these certificates cannot be evaluated, because the underlying test reports are not public [6]. Majcen [2], Santin [3], Fabriek [7] indicate that some building indicators are important for the energy consumption: ventilation rate, g-value glass (solar transmission factor), the wall heat transfer coefficient, and the heat gain. An important behavioural characteristic is the number of bedrooms heated (Santin) and the number of hours the heater is set at higher set-point. The better the dwelling is insulated, the less important is the temperature set-point, but the more important is the ventilation rate, the orientation towards the sun and indoor heat sources from persons and electrical appliances [7].

Some of these factors are highlighted in the following design choices in renovation projects: ventilation system, type of heat distribution, thermostat control, glazing type.

Ventilation system

About 50% of the housing stock and even more renovation projects in the Netherlands have natural inlet/exhaust ventilation. Exhaust ducts are poorly maintained and often wrongly used by blocking the exhaust duct with temporary-used bathroom fans or cooker hoods. The ventilation system is perceived responsible for mould problems in bathrooms and for draught complaints. In renovation projects the standard improvement is to install mechanical exhaust and to improve natural inlet services. Providers of ventilation products promote direct current fans, demand control and heat recovery.

When users have control over the set--point of mechanical systems, more than 80% chooses the lowest possible set-point, and air volumes are lower than before the renovation with natural ventilation [8], which potentially creates more mould problems. Demand control is normally based on CO2 concentration and will reduce the air change rate to maintain concentrations below for instance 700 ppm. This strategy can prevent peak concentrations if the ventilation capacity is high enough in the CO2-monitored room. Energy saving comes from lower fan electricity use and lower heat losses.

Overall, mechanical systems contribute less to practical energy savings than is suggested by providers, mainly because the systems are not used according to the input parameters. Important design criteria for renovation are often not met: flexible use, safety of natural openings, comfort both in winter and summer, contribution to summer “night-time” cooling, low noise level and high ventilation capacity especially in bedrooms. In well-insulated dwellings the heat demand is low and the period with preferred energy efficient ventilation is rather short. Both hybrid natural/mechanical exhaust ventilation and heat recovery ventilation are possible solutions for the short winter period in moderate climates. The decision to abandon natural exhaust is not based on good diagnosis and can be wrong.

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Local versus central heating

The strategy in renovation projects is to install central heating at turnover or when tenants ask for it. Because of the high rent increase involved (> € 45- per month after correction for replaced appliances) the tenants have to agree with the change and this makes central heating a free-selective measure when occupied dwellings are renovated. Before the renovation of the Delft Beem-Up project, many apartments had either one chimney tied gas heater or the mother-fireplace in the living room with radiators in all other rooms. The tenants that still use a single chimney tied heater are satisfied with the improved comfort after insulation of the envelope, while showing lower energy consumption than in dwellings with central heating []. These findings raise the question of priorities in renovation. Better insulation of the envelope would increase the overall temperature without heating due to solar and indoor gains and lower heat losses to a degree that meets the needs of tenants who prefer unheated bedrooms. The combined heating/hot water appliance has developed into a high performance and cheap appliance, meaning that radiators are just needed in the living room and kitchen.

Temperature control of central heating

The EU directive [9] states that metering and individual billing must become standard, at least quarterly but preferably constant and at all time available for individual consumers. Modern energy feedback systems combine the thermostat function with feedback, with the intention of learning and to stimulate energy efficient behaviour. The question is what energy effect we can expect from the different metering and control systems in renovation projects.
The On-Off thermostat is user friendly and robust. The direct feedback leads to pro-active control behaviour: down when going out or one hour before going to bed, no heating while asleep, higher when the household tends to sit down in the evening etc. The clock thermostat allows pre-selection of certain temperature levels at different times per weekday with repetition of the week cycle. Santin [] found that the average temperature set-point with clock thermostats is lower than with manual thermostats, but the heating hours are longer and the clock thermostat ends up with causing higher energy consumption.

According to Dam [10] “home energy management systems (HEMS) are defined as intermediary products that can visualize, manage and/or monitor the energy use of products or entire households. They are intended to give households direct and accessible insight into their energy consumption and thus help them to reduce it.” A smart meter generally needs a HEMS to give users the intended insight [10].

Figure 7. The display of TOON next to the application for a smartphone, products of ENECO energy company, NL

The HEMS in the Beem-Up project in Delft is called TOON and can give information on:

-Real time power use (electricity) and heat consumption;

-Comparison of electricity and natural gas or heat with the previous day, week, month or year;
-Expected energy consumption both in energy units (kWh and m3 natural gas) and in Euro's;
-Comparison of energy use with the average in the neighbourhood;
-Actual temperature and manual adjustment of the set-point for the actual period;
-Pre-set period with four set-points: away, home, sleeping and comfort;
-The weather (expected rain showers).
Interviews with users indicate that the real time information gives new insights and does have effect on behaviour. The learning curve is fast and will last a few weeks, but energy or cost minded people stay interested the energy consumption. When being faced with replacement decisions, they are more likely to take an A++ type refrigerator or a LED television, while taking long showers may be discouraged on the basis of the energy effect.

The TOON is a free service for two years, after that period the tenants have to pay a monthly fee of € 4,0 to € 5,0. Dam [10] found that the energy saving effect over period of months is around 7%, which is about 50-60% of the cost for using it. Almost all interviewed people choose to continue using the HEMS.

Double, triple or vacuum glazing
The last decennia have shown innovation in glazing. U values tumbled from 6 W/m2K to 1,1 -1,2 W/m2K. Now the focus is on triple glazing (U=0,5 -0,7) and vacuum glass appears at the horizon, again with the promise of reducing the U-value by 50%. In renovation projects the choice is between standard double glass (U=1,2) or triple glass (U=0,7). There is more to the comparison that the difference in U-value: the difference in embodied energy is large (mainly caused by Argon), the investment cost is higher, the panes are thick and heavy requiring strong frames and hinges, the handling of windows and doors is lees user friendly, the architect faces restrictions in shape and size, etc. Solar influx has more impact on the energy balance than the U-value. Over the whole year for The Netherlands there is no relevant difference in the energy balance of a dwelling with double glass and triple glass [11]. For the cooling demand triple glass wins, while the acoustic insulation and also the inner surface temperature of triple glass provides more comfort. Vacuum glass is becoming commercially available, but still at high cost. The extreme insulation value, high transmittance, low weight and small thickness due to a cavity of only 4-5 mm makes this innovation welcome and may push triple glazing aside as a detour in the transition towards better energy performance of building products.

Conclusion and Recommendations
High insulation level and good sealing are the first design steps in renovation plans. When the EPC tightens from 0,6 tot 0,4 in 2015 a practical check will be introduced in the Netherlands and this could promote the use of actual energy data in the renovation process. Renovation plans with high insulation level and simple ventilation, heating and hot water services with low standby energy use are most likely to save both cost and energy over a long period of time. Advanced collective ventilation and heating services may cost more, also in energy

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consumption including embedded energy, than robust individual climate systems. A group of energy conscious occupants can be supported with smart energy feedback systems, but selective use and short heating periods are the key to low energy consumption.
HR++ double glass deserves priority over triple glass in a moderate climates (Netherlands, France) and extra insulation deserves priority over heaters in all rooms. Providing a choice of ventilation options for the varied needs of users is the key to healthy and comfortable housing. Low energy effect of renovation tells more about the people than the technology used.

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Sustainable retrofitting guidelines through an energy simulation-based method. Feasibly study on the social housing buildings in Agia Varvara, Athens

Abstract: More than 75% of the buildings that make up the European real estate assets have been designed and built earlier than 1976 in total absence of specific rules and regulations concerning thermal insulation and with very few considerations on energy efficiency [1]. Within the current discussion on the feasibility of energy retrofitting buildings' operations, the pilot-study developed in this research offers an updated review of the possible methods and techniques to be applied to reduce the energy consumption in existing buildings. As case study, the research team has selected a building block in Agia Varvara (Athens) to test a new computational method based on the energy simulation that have been run considering the current condition of the building. From the analysis of datas that have been collected, a set of guidelines has been produced in order to define which are the most effective interventions. Up until now, the application of identical and standardized strategies have shown its limitations when it comes to the existing building stock which is characterized by an enormous variety of building typologies and a wide set of environmental, social and economical conditions. The aim of the research is to define a direct connection between the results of the energy simulations (Energy Plus software) and tailored design, thus creating a cause-effect link between the current situation and the possible energy retrofitting strategy. The proposed method overcomes the standardization of the renovation practice and increase the effectiveness of the retrofitting actions, showing the great potential of a tailored designed approach.

Energy efficiency refurbishment, EnergyPlus, Envelope performance, dynamic simulation,

Energy refurbishment for social housing building though tailored solutions

Buildings represent the largest untapped source of cost effective energy saving and CO2 reduction potential within Europe (at least 22% of energy used in buildings can be saved by intervening on energy efficiency [1]), yet the sector continues to suffer from significant underinvestment. The aim of this research is to evaluate the energy performance of buildings for the Social Housing in the Mediterranean climate, to identify the main problems concerning energy needs, both in winter and summer conditions. In the Mediterranean area the relationships between energy and building create more complex relations between energy valuation and building design. In this way the architecture typology and historical construction techniques could be a reference to satisfy indoor comfort. [2] The research is trying to define existing relation between the internal distribution and the building orientation, to evaluate how these variables effect the energy balance and the thermal behavior. Tailored and specific guidelines for more efficient renovation actions are fundamental to propose a shift in the practice and avoid standardized interventions that are not able to answer to the real condition of the buildings. A sustainable information framework is seen as an attempt to

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address some of the known factors by providing informed choices towards sustainable design within a software-based design environment. [3] Only through this targeted, sustainable and durable interventions it is possible to improve the sustainability of buildings towards a Net ZEB (Net Zero Energy Building). This study is part of a broader research which has the final goal of defining an integrated methodology that considers not only the merely energetic and consumption aspects but can bond also the social aspects directly related to the various inhabitants' need and expectations, linking therefore demographics to environmental attitudes and behaviors to the current energy requirements. [4] In this paper the software evaluations carried on the building in Agia Varvara are presented, the main objective is to investigate and evaluate numerically the effective implication of the internal distribution and orientation on the energy consumption of the building to define where and how to intervene to improve the performances of the building from the technical side.

Research case study: Agia Varvara, Athens

The chosen case study is a Social Housing intervention built in the '60s located in Agia Varvara, a densely urbanized neighborhood in Athens. The urban configuration of the area is highly relevant: the repetitive urban layout allows the contextual analysis of the same building typology within the same context but different orientations and different internal layouts.

Image 1. Aerial View of Agia Varvara. In the three blocks are located fifteen buildings oriented according to the North-South and East-West directions. The classification among the buildings: oriented along the East-West direction with the living areas facing North (A1), oriented along the East-West direction with the living areas facing South (A2), oriented along the North- South direction with the living areas facing West (A3), oriented along the North- South direction with the living areas facing East (A4).

It is evident that applying the same strategy and the same type of intervention for all these building would not be effective in a refurbishment program thus sometimes even counterproductive. Moreover, the choice for a Mediterranean climate context is ideal to evaluate the behavior of the architectural shell to climatic conditions that are very different throughout the year. Considering the intention of involving the inhabitants in the process it is important to take into account the ownership profile of residential buildings in the greek social housing sector, in Greece entirely private [5]. All the buildings in Agia Varvara can be traced back to a common planimetric typology: four-floor high blocks, with two internal staircases that serve four apartments each floor, for sixteen apartments in total.

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The structure is made of reinforced concrete, walls are made with blocks externally treated with plaster; the entire structure of beams and pillars is totally exposed and represents a severe problem for the thermal performance of the envelope. It has been estimated that many of the problems of the building can be significantly improved through specific intervention directly on the architectural envelope as it is of strategic importance for a sustainable refurbishment that goes in the direction of decreasing the energy impact. In Greece, thermal insulation (in walls, roof and floor) and low infiltration strategies can reduce energy consumption by 20–40% and 20% respectively. [6] The tetralogy structure/envelope/partitions/plants, considered up to now in its mono-directional identity of technical and creative expression of its designer, leaves space to subsequent actions of performative upgrade [7] of the building sub-systems, to energetic retrofitting and to a direct involvement of the end user in modifying the house configurations to the changing of one's own needs.

Simulations analysis: internal distribution, building orientation and envelope performance

The building block has been divided into four different typologies according the existing relation between the internal distribution and the building orientation (see Image 1), to evaluate how these variables effect the energy balance and the thermal behavior. The physical characteristics and thermal properties of the surfaces that determine the amount of energy lost in winter conditions, govern also the evolution of the heat balance in summer conditions: worst characteristics mean greater energy requirements to reach and maintain the set-points of temperature, humidity, ventilation and comfort, both for the heating system in the cold season and for the cooling system in the hot season. In order to make a correct comparison, the apartments were simulated considering all the rooms and the activity that take place into, merging the spaces into a living area (made up of kitchen, bathroom and living room) and a sleeping area (made up of bedrooms) data. The software that has been used is EnergyPlus, a modular, structured code based on the most popular features and capabilities of BLAST and DOE-2.1E. It is a simulation engine with input and output of text files. The EnergyPlus building systems simulation module, with a variable time step, calculates heating and cooling system and plant and electrical system response. This integrated solution provides more accurate space temperature prediction—crucial for system and plant sizing, occupant comfort and occupant health calculations. [9] For each apartment within each building of the four considered types, simulations have been run in the coldest day of winter (15th of January) and in the hottest day of summer (25th of July) : as expected, the apartment which has the greatest dispersion is located in the top corner position because it has more surfaces in contact with the external environment than the other apartments, so it has more dissipations through external walls and roof. The one that has less dispersion is located in the central position, because most of its external surfaces are in contact with equally heated environments, the total dispersion is less because there are smaller dispersions through each single surfaces. Generally we tend to consider the orientation of the building a feature of secondary importance and do not take into account the impact that the arrangement of the interior spaces has, in relation to the energy efficiency of the system. The study carried allows

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to assess and numerically evaluate the impact this factor has on the local conditions of comfort and on the quality of the confined environments, as well as on the energy balance and on the future consumptions of the building.

Considering both the winter and the summer conditions, the benefits and disadvantages, the building oriented in a more efficient direction seem to be the building A2, with living area exposed to South-27° West and the sleeping area to North-27°East. In winter conditions is able to maximize the positive solar gains through the windows, which allow to reduce the heating load required to achieve and maintain comfort conditions. The building oriented in this way takes advantage of the higher solar gains to reduce the heating loads, and so the consumptions. In summer this arrangement has also an ideal behavior, limiting the period in which it receives direct solar gains through the windows. Throughout the analysis phase, the data were presented in terms of needs and contributions, but according to the general aim we present now some conclusions using the indices Epi (index of primary energy for heating in winter) and Epe (index of primary energy for summer cooling) as parameters of comparison, calculated according to their respective periods.

	Epi_{lim} (kWh/m^2 year)	Epe_{lim} (kWh/m^2 year)
A1	99	68
A2	91	69
A3	94	76
A4	90	74

	Epi (kWh/m^2 year)	Epe (kWh/m^2 year)
A1	84	58
A2	78	59
A3	80	65
A4	77	63

Table 1. The values in the table on the left have been calculated not considering the plants and thus represent the requirements of the building during the heated period (from 01/12 to 31/03) and the cooled period (that is the remaining period, from 01/04 to 30/11). The values on the right indeed assume an efficiency of the plant system η=0.85.

From this analysis, it is also clear that the exposures that have a good behavior in winter conditions could not have in summer conditions. The graph in table 2 shows the results the simulation carried out on an annual scale on the building A1: indeed the situation is different from week to week and is generally different from the ones of the weeks considered (indicated by the red lines). The two weeks chosen can show the behavior of the building under the worst conditions that may occur, looking at the period adjacent to the weeks considered, we see that the conditions of temperature, pressure and humidity (which are not listed here for brevity) are quite similar in that period of time, as are also similar the factors of the thermal balance. From the annual simulation is also noticeable that in the intermediate seasons near the period of switching on or off of the heating, the building as a whole, requires a heating load and at the same time a cooling load. To reach the temperature and comfort set-points there is the need to heat certain areas at certain times and to cool other (the data are obtained as sums of individual contributions and not as averages). To obtain data comparable on annual scale in order to evaluate also numerically the performance of the various buildings and compare them, it has been chosen to use again the indices Epi and Epe, calculated according to their respective reference periods and reported to the entire year.

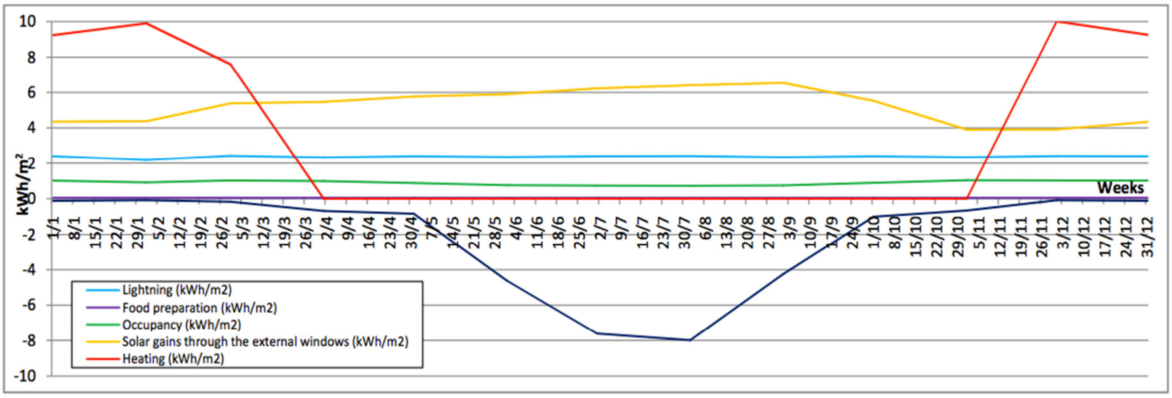

Table 2. Results of the simulations carried on building A1, on annual base

It is important to consider that these benchmarks are useful to perform a comprehensive comparison between the buildings, but they incorporate a media operation that gives a good idea of the general behavior of the building. However the individual apartment not necessarily have the same value, locally, of the ones collected for the global system as a whole, in this case the entire building. If we evaluate the loads required by the single apartment in the reference periods, the numerical values that can be found can be also very different, especially in those apartments conditioned by peculiar adjacency characteristics (such as the apartments on the ground floor or on the top floor as explained above).

Envelope components guideline for a tailored made renovation practice

The previous analysis phase showed how a bioclimatic approach to the planning phase is of strategic importance to pursue the goal of a sustainable architecture: proper site selection, building orientation and organization of the block play a very important role in defining the future quality of life in the interior spaces and the future consumptions. In case of refurbishment and renovation though, these aspects are not variables to be defined, but they are generally critical features or strengths, starting points for the (re)design phase. The basic principles that can inspire design proposals in the refurbishment practice can be group in three main streams: 1. reduction of energy requirement for heating and cooling through passive interventions on the building envelope; 2. reduction of consumption (at the same performance level) by improving the efficiency of the systems; 3. active production of renewable energy to cover and balance the consumptions. The set of all the features of the building, in response to external environmental conditions, requires a certain amount of energy in order to establish and maintain the comfort conditions expected within the interiors. The equipment to produce

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this amount of energy required is the system, which needs to turn to a power source for this operation: the consumption is therefore the amount of incoming energy which the system needs to reach the comfort level. The interventions on final consumption or on systems are not going to change the overall energy requirement balance of the building, but aim to change the way in which the requirements are met. The most direct renewable source is certainly the sun, especially if we refer to Mediterranean climates, therefore a boundary condition in the project needs to be considered: the absorbing surface needed to power the technological systems chosen in order to cover the remaining consumptions. The passive interventions are instead finalized to decrease the amount of the needs, and consequently decrease the consumptions. The factors that define the requirements are the climatic conditions of the site, the expectations of comfort of the users and the characteristics of the building. Exploiting some of the bioclimatic considerations that are also the basis of the rules of the traditional architecture, the time periods in which the spaces should be heated in winter and cooled in summer can be minimized, which means extend the conditions of the intermediate seasons. These histograms suggest what might be the architectural elements that need work on, to get more interesting feedbacks: mainly the roof and the windows, then the walls and the floor against the ground.

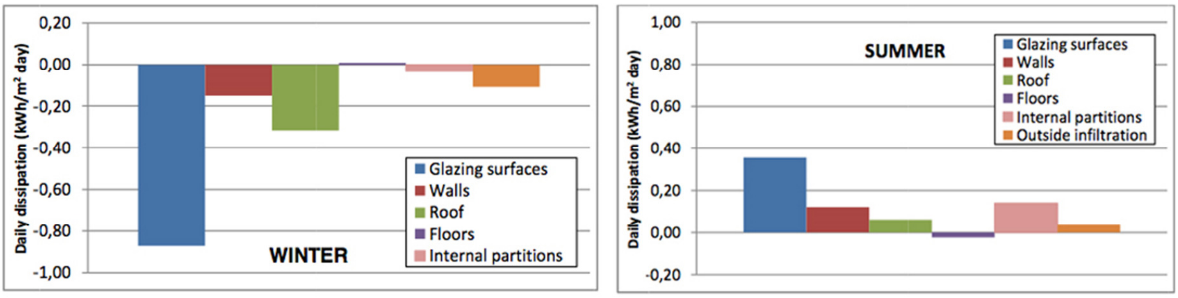

Table 3. Daily dissipation in winter and summer conditions, datas refer to the apartment that has been found in the worst energetic condition, corner top dwelling in building type A3.

The passive strategy that inspired the series of proposals here presented is based on increasing of the thermal inertia of the building through the introduction of insulating materials or parts having better thermal performance. The physical quantities which determine the thermal inertia are the thermal capacity (which itself depends on the mass), the difference of temperature between the two sides of the surface and the transmittance K, indicated by many European regulations also with the symbol U. To evaluate the effectiveness of the proposed solutions, a simulation of the building before and after the intervention was carried out on annual scale and were calculated indices of primary energy for heating in winter (Epi) and for summer air conditioning (Epe), which were then used for assessing the usefulness of the intervention along with the amortization time of the investment. For each proposed intervention has been reported the indices Epi and Epe, summer and winter consumptions

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before and after the intervention and the cost for consumption, all measured per apartment. Consumptions were assessed under the same systems conditions and the cost of consumptions was estimated applying the average energy tariffs in force in Greece for domestic residential users., i.e. 0,102 €/kWh of gas and 0,145 €/kWh of electricity. A summary evaluation of the costs of the various interventions using the current prices enables to compare the cost of the refurbishment with the savings and payback time of the initial investment (see Table 3)

PROPOSED REFURBISHMENT INTERVENTION	Ep in winter *before* (kWh/m2 year)	Ep in winter *after* (kWh/m2 year)	Ep in summer *before* (kWh/m2 year)	Ep in summer *after* (kWh/m2 year)	COST per apartment (euors)	SAVINGS per apartment (euros/year)	PAY-BACK time (year)
ROOF INSULATION mineral wool thermal coating and restoration of the topcoat with waterproof membrane ballasted with gravel	100	92	67	62	572	245	2
GREEN ROOF anti-root membrane, drainage layer and filter layer. The moist soil that can be planted with grass with underground watering system.	100	93	67	62	1155	245	5
INSULTAION+ ALUMINUM SHADINGS replacement of existing shutters with movable shading elements	100	85	67	55	1000	104	10
ROOF INSULATION+NEW WINDOWS new thermal break aluminum window frames with double glazing, thickness of 1.3 mm with air camera	100	79	67	52	2090	380	5

Table 3. Comparative evaluation of the possible interventions proposed

Conclusions

The simulations carried out have largely confirmed the validity of the rules used in traditional architecture for choosing the optimal site and proper disposal of interior spaces and buildings orientation, justifying these statements with quantitative evaluations of the related phenomena. The proposals made for the refurbishment of the buildings in Agia Varvara has started by the definition of the most effective portions and component of the building that needed to be treated. The most effective strategy for this buildings consisted in passive interventions, different in potential benefits and costs, but all aimed at improving the performance of the elements that were found as problematic during the analysis. It has been shown that even with simple and inexpensive passive interventions on the right features it is possible to reach interesting savings in consumption, it is therefore important to first analyze the condition of the building in the specific context and understand where and how to intervene. Standardized insulations and pre-made receipts are not the effective and sustainable solutions that we are looking for, indeed they can become highly counterproductive especially in hot climates. The final question of the research was investigating the real possibility of achieving a Net Zero Energy Building standards. It is possible to turn an existing building into a Net ZEB but it is a highly expensive goal because of the need to perform both active and passive interventions, which can be amortized only over a relatively long pay back time.

Renovation projects in residential areas give an opportunity to target the installation of Intelligent Energy Systems in large numbers of houses but this implies that local stakeholders need to be persuaded to adopt IES. Although innovative renewable energy and energy efficiency technologies offer great opportunities to improve the energy efficiency performance of housing in residential areas, in practice, conventional energy systems and middle-of-the-road insulation materials are still today preferred. Although local authorities are considered key actors to achieve environmental [10], and climate (energy) goals, they very much depend on the willingness of local stakeholders to comply to their plans. [11] Considering the reality of an entirely privately owned condition like the Agia Varvare case study, the cost and benefit analysis of reaching a Net Nzeb is not favorable. Taking into account the life-time of the IES and the life-cycle of the existing building itself, even if it is an achievable goal, reaching the Zero Energy Building is today still hardly feasible.

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Building Our Capacity to Reliably Achieve Climate-Neutral Building Outcomes

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Abstract: *Our primary objective as a global green building community is the development of projects with extremely low carbon intensity. We have the technologies to achieve radically improved performance. What is lacking is the widespread understanding of the organizational capacity-building needed to accomplish it. Those steps are, from last to first:*

5. Establish quality management processes, coupled with measurement and verification to validate results.

4. Pursue intensive collaboration throughout the project.

3. Engage individuals qualified to achieve the targeted levels of performance.

2. Adopt an integrated project delivery structure.

1. Set quantitative performance goals early and pursue them rigorously throughout the project.

These steps represent a demonstrated framework for capacity-building, enabling design and construction teams to achieve unprecedented levels of building performance.

Key words: climate-neutral, low-carbon, integrated project delivery, integrative process, high performance, measurement & verification

Preface

I am neither a scientist nor an academic; I am a practitioner. This paper, therefore, represents not a scholarly study nor scientific analysis. Rather, it is a position paper based on 35 years of practice in the built environment, the last 20 of those years focused on advancing the practice of sustainable design and building. Throughout these last 20 years, I have been engaged in teaching and coaching project teams regarding their adoption of these ‘advanced’ practices, as well as collaborating with other colleagues likewise engaged.

Since late 2010 I have served as chair of the Green Building Construction Task Force of the Commission for Environmental Cooperation (CEC), a tri-national body formed by the United States, Mexico, and Canada to pursue environmental agendas of mutual interest. Our task force was charged with the mission of ‘improving conditions for green building across North America.’ During the 2013-15 program cycle, under my leadership, one of our tasks has been the development of a guide for project teams to implement integrative processes (IP), including integrated project delivery (IPD). For this purpose, the CEC engaged a team of IP and IPD pioneers, who are currently working to develop this guide.

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This paper sets forth a suite of requirements – necessary conditions for the consistent, successful, and cost-effective realization of building projects with high performance goals – based both on findings of the CEC's IP/IPD task team and on my own participation in projects where high performance goals were pursued but either not realized, or realized only after the teams experienced challenges during design and construction. In other words, these are conclusions reached through the familiar process of trial and error, and close examination of the causes of the errors and subsequent adoption of practices to avoid their repetition in the future, thereby facilitating improved outcomes.

Collectively, in my own terms, these conditions or practices represent what can be broadly described as capacity-building; and at the core of the capacity-building framework is integrative process or integrated project delivery. (However, to facilitate adoption – because more of the design community is familiar with "integrated design" – I propose use of the term, *integrated design and delivery*, abbreviated ID+D or ID^2.) A commitment at the highest levels within the funding and/or development organizations to this capacity-building will enable successful implementation by experienced and creative practitioners within the green building community.

Introduction

Our primary objective as a global green building community is the development of new, decent housing in parts of the world experiencing population growth; and in more-developed parts of the world, the extensive rehabilitation of our existing building stock. In both cases, this must be accomplished with extremely low carbon intensity of both the input materials and resulting building operations.

We know that we need to set such ambitious performance goals in order to achieve necessary reductions in building-related carbon emissions within the critical window for those reductions to occur – in round numbers, the International Panel on Climate Change tells us, the next 20 years. It is incumbent upon us, then, to do so as quickly and as successfully as possible. The goal of this paper is to equip design and construction teams to make this leap, quickly and smoothly rising to a much higher level of performance.

From a technology and materials perspective, the knowledge exists to do this now. The sustainable building community knows what is necessary to renovate, build, and operate residential and commercial buildings with radically improved environmental, economic, and social performance as compared to past building practices. What is lacking is the widespread recognition in our building professions and institutions of the conditions and methods necessary to accomplish these ends, and practice in their implementation.

Sustainable Building Requires Change

The first required condition is full recognition that the adoption of sustainable or high-performance building goals necessitates fundamental change – more explicitly, an evolution in processes of the production team (architects, designers, engineers, construction contractors, and trades people) better-suited to producing a new, improved, product.

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Imagine if a manufacturer of economy automobiles decided to enter the market for high-performance autos, competing head-on with BMW, for example. In the auto industry – and most others – such a shift would be seen immediately for what it is: a major undertaking requiring a host of efforts by the production team to ready themselves for the new product launch. The steps might include:

- Reverse engineer the competing product;
- Research new materials and methods;
- Establish new vendor relationships;
- Create new procedures;
- Revamp the production line;
- Set up quality management systems;
- Educate workers;
- Hire new staff;
- Develop new approaches to marketing and sales.

All of these activities – which may be collectively referred to as capacity-building – translate quite well to the building industry. And yet this is not how project teams who embrace the challenge of producing a new, higher-performing building product typically approach that task. Rather, they tend not to fully appreciate the significance of their undertaking, treating the new performance objectives as minor adjustments in their *normal* process. Deceptively, this may work if the new goals are 'baby steps' – truly minor changes to the product, such as switching to low-VOC paints.

However, all but the most trivial changes in performance carry unforeseen impacts to business as usual. Let's look at another product switch, for example, use of wood products certified under the Forest Stewardship Council (FSC) management system. It's just a label, right? Yes and no.

Yes, FSC-certified products may be identical in appearance and performance to their non-FSC counterparts. But the practices of design and construction oriented to the use of FSC-certified products require some changes. These changes arise from the fact that FSC-certified products, while considerably more widely available now than in the past, are still in lesser supply than non-certified wood products.

From a design perspective, this may mean consideration of alternative types of wood for a given application; for example, the use of lesser-known species. This deviation from the known and familiar requires added research about species availability in the local supply chain, and in turn research about the material properties of the available species – including visual appearance – prior to selection of a product.

For the construction team, use of FSC-certified products may require establishing new vendor relationships, planning for longer lead times, and in some cases learning new techniques for working with unfamiliar species. For example, there are some tropical hardwoods that can not be installed with nails, but instead require use of screw fasteners. In addition, conscientious purchasers of FSC products need to be aware of FSC's chain-of-custody requirements, and ensure that they are in fact buying products from sellers who hold chain-of-custody certification.

As more ambitious performance goals are adopted, they pose more and more far-reaching, systemic effects, even, than illustrated by the FSC example. What happens when you decide to use a layer of continuous exterior insulation, in order to prevent thermal bridging through the building's framing system? There are many design and construction consequences of this decision, including requiring new fastening methods for cladding, deeper window and door frames, and adaptations to flashing methods.

Each of the foregoing examples represents a relatively minor performance reach. Adopting a more comprehensive goal, such as zero net energy, inevitably entails a host of collateral changes with deep and complex implications for both design and construction.

Successful (happy, cost-effective, trouble-free) realization of such ambitious goals, then, requires organizational retooling, or capacity-building. Without it, the project team is destined to encounter unforeseen stumbling blocks at every turn, each one resulting in consternation, confusion, and delay – at best – and at worst, omissions in design and errors in construction. These outcomes are costly both in monetary terms and in social and professional capital, adversely affecting not just the individuals directly involved, but the larger sustainable building community as well, as they may cause setbacks in market confidence regarding the reliability of sustainable building methods.

Capacity-building Framework

Development of a high-performance production capability requires undertaking the following critical steps – collectively, a *capacity-building framework*:

1. Set quantitative performance goals.
2. Adopt an integrated design and delivery structure.
3. Build a qualified team.
4. Maintain collaboration continuously.
5. Manage quality, measure and verify performance.

Inasmuch as successful execution of each step is dependent upon those preceding, I'll discuss these steps in reverse order.

Quality Management

Continuous quality management processes are needed to ensure building integrity, including measurement and verification (M&V) of performance results to ensure that the performance goals set for the project are being achieved.

A critical tool for M&V during design is use of a reliable energy simulation model. The model should be used iteratively to test the effects of various design hypotheses on building energy performance and to compare the relative benefits of different energy strategies, such as high-performance glazing and elevated insulation levels. This is critical to optimize design.

Examples of quality management or M&V during construction include diagnostic testing such as pressure testing with blower doors (fans) to determine rates of air leakage in the building enclosure, inspection of framing to avoid thermal bypasses, and inspection of insulation to ensure quality installation. Ideally, construction M&V should be done by the trade workers; this in turn requires teaching the M&V techniques to the construction workers so that they can monitor and validate the quality of their own work. This approach has been demonstrated to be much more cost-effective than third-party diagnostic testing after the fact (1).

Collaboration

Collaboration, per se, is nothing new in the world of design and construction. It is the degree and extent of collaboration in high-performance projects that distinguishes them from more conventional projects. It is customary to begin a high-performance project – one with advanced sustainability goals – with a *charrette*, an intensive all-hands workshop that is typically at least one full day and sometimes multiple days in duration. The charrette ideally will be conducted as early in the project development process as possible, and will accomplish at least three critical objectives: establish and/or refine the project's performance goals and metrics; begin the team's dialogue about the basis of design; and set the tone and expectations for further collaboration throughout the course of the project.

Sustainable building projects often involve multiple charrettes, conducted at pivotal stages in the development of the design and involving specific contributors based on the aspects of the design under consideration.

Between charrettes, the teams maintain communication regarding the development of the design, meeting and conferring frequently to ensure that every aspect of the design is optimized through utilization of the collective knowledge and insights of the team members.

One important outcome of this process of ongoing, intensive collaboration is shared responsibility for learning amongst all team members, sometimes referred to as "co-learning" (2). Another is the development of closer-than-normal professional relationships, with the distinct benefit of more harmonious interpersonal interactions, in turn producing happier participants, greater productivity, and improved sense of purpose and goal-seeking; all of which contribute to successful achievement of the advanced performance goals of the project.

Team Formation

Even with M&V, consistent achievement of high-performance results requires a team whose mindset from the start is guided by the desire to achieve the project's ambitious performance goals. There are three critical qualifications for team members: commitment, experience, and creativity. Commitment is non-negotiable; an individual who is not committed to the performance goals, and who does not play well with others, should not be a part of the team. An appropriate and relevant body of experience – i.e., demonstrated ability to meet the types of performance goals set for the project – is also essential, as is a creative faculty.

All three of these attributes may not always be embodied in a given individual team member, however, so which requirement should give way? Opinions on this vary. In general, though, if one trait must be sacrificed over the others, it should be either experience or creativity, never commitment; and the team as a whole must possess a solid foundation of experience and a liberal degree of creativity, even if individual team members may lack one or the other of the latter two traits. (I have polled hundreds of building professionals on this subject, and there is a strong consensus, as stated above, that commitment is a non-negotiable requirement for every team member. However, views are roughly split on whether creativity or experience is a more essential characteristic.)

Integrated Design and Delivery

Pioneers in the sustainable design community are in strong consensus regarding the conclusion that they achieve the highest performance results when they pursue an integrated (or integrative) approach to design – that is, all members of the design team are engaged in early and continuous collaboration, in order that the project may fully benefit from their aggregate experience, skill, and insight. The relatively newer and even less well-known practice of integrated project delivery extends this logic to the process of construction, as well, engaging the general contractor and key trades from early stages of *design*, with the goal of achieving a highly-integrated building project. (While definitions and implementation of ID+D vary among practitioners, the preceding captures a generalized view of the ID+D process.)

Design and construction are typically discussed as though they are distinctly different activities, occur in different time frames, and are done by different people. In reality, a design is almost never *fully* envisioned and realized until shortly before construction is finished; and a successful, optimized design cannot be developed without a thorough understanding of the concrete realities of construction – both procedure and cost – which are never more critical than in leading-edge projects. This means both that the construction team members need to actively participate in the design process, and that the design team needs to remain engaged throughout the course of construction.

One aspect of collaboration that is present in some, but not all, ID+D processes is the use of contractual structures that share legal responsibility for achievement of performance goals among the three principal project parties: owner, architect, and builder. Although it is an important emerging field of practice, there is not room in this paper to discuss these legal structures; however, ample resources exist on this subject (3).

Performance Goals

Just as, if you wish to reach a distant, unfamiliar destination, you must have a map and navigational aids, quantitative performance goals must be established at the outset of a high-performance project and pursued rigorously throughout its course. Each goal, such as "energy efficiency," must be accompanied by metrics and objectives as specific as possible, to guide the design and construction process and provide the basis for subsequent evaluation activities. It is also critical that the full support of the project principal (the owner or developer) underlie the performance goals. Without this foundation, the production team members will have great difficulty adhering to those goals themselves.

Intimately related to goal-setting is the issue of cost. All too frequently, sustainable building goals are reduced to “features” and subsequently assigned a cost; these “features” are then subject to the process of “value engineering,” in which efforts are made to trim costs with the frequent outcome that sustainable performance is compromised. This reductive process is often a byproduct of inadequate goal-setting, or lack of sufficient clarity in the establishment of performance metrics.

When clear and unequivocal performance goals and metrics are established, they are not “extras” that can be subtracted from the project without compromising the resulting product. No more than a home can be a home without a kitchen, or a car without wheels, can a sustainable building project be considered successful without achieving its established performance goals.

This viewpoint has been uniquely well-expressed by U.S. architect Bruce Coldham: “It is often presumed that ‘green’ resourceful building involves a cost premium. This is not a universal truth. Though it is reasonable to assume that a superior product should come at a premium, good performance enhancing design is more a matter of examining design goals and objectives with a view to redirecting investment. On this basis, a performance enhancement can be seen as favoring one option over another – a choice rather than a cost premium.” (4)

Conclusion

A well-articulated capacity-building framework is needed to enable project teams to successfully achieve high-performance results on sustainable design projects, surpassing their performance on past projects and thus ever improving the practice of sustainable building. This is a crucial recognition in the green building community’s efforts to develop climate-neutral (or better!) projects. Without undertaking the necessary steps of building organizational capacity, production teams are destined to experience chronic frustrations and shortfalls in pursuit of their sustainability goals. With proper focus on improvements in capacity, conversely, the high performance outcomes are much more readily achieved.

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Lack of Sustainability Assessment as a rating tool in the Building Industry – KSA

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Abstract

Sustainability encompasses a blend of environmental, economic and social responsibility. Sustainability assessment is a means of measuring how effectively the built environment is meeting the requirements of sustainable development. The Middle Eastern regions records in the 1980's especially KSA, due to demographic growth, there has been; population increase, climate change, land exploitation and water shortage; thus tending environmental issues. Latterly, there has been an increase in the Arab concern as to environmental issues.

Saudi Arabia, being one of the top 15 countries in the world in terms of primary energy use, due to a rapid increase in economic and industrial growth. Records from Saudi Electricity company ' SCECO' bespeak that; almost 80% of total energy is use in the building sectors, with 70% resulting from use of HVAC systems. KSA recorded a 7% yearly consumption in petroleum for local use, by 2038, petroleum production will be diverted to local consumption- (Royal British Institute for Strategic studies). Withal, Middle east countries especially KSA are far behind from practicing the concept of mitigating the impacts of buildings on the environment.

This paper entails an exclusive questionnaire study on; Policy makers (Government bodies such as 'Real-estate'), Architects/ designer, Contractors, and the end user as to sustainability application in general. Notwithstanding, analysis indicated; insufficient awareness of building stakeholders, lack of national sustainability assessment policy, which takes the location and the context of the building in KSA that deviate the people from caring for environmental and economic issues related to sustainability.

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The purpose for this paper is to; highlight the obstacles faced in applying sustainability in the building sector of the Kingdom of Saudi Arabia (KSA) by various stakeholders.

Keywords: ***Sustainable Assessement, rating tool, building industry.***

1- Introduction

Saudi Arabia is a developing country in the Arabian Gulf region that has been growing dramatically over the past two decades. It is estimated about total population about 21,846,884 in 2003 (Central Department of Statistics-Demogrpahic 2003). The total landspace of the Saudi Arabia is about 1,960,582 sq. km. (climate-zone 2004). Thetotal owned houses are about 1,526,678 and the total of leased houses is about 1,520,693.(Central Department of Statistics-Demogrpahic 2003). According to the UNICEF, 82% of the population is urbanised (UNICEF 2010). With the growing evidence that the phenomena of global warming and climate change are caused by anthropogenic greenhouse gas emissions [1], it has become necessary to take immediate action to avoid dangerous consequences for future generations. While not exclusive to any particular certification system, many studies discuss the barriers the promoting of sustainable construction meets (Lee, Yik, 2004; Matar, Georgy, Ibrahim, 2008; Osaily, 2010), which illustrates the need for policy measures or helps to understand why policy tools are not as successful as expected. It's important to understand that in most cases markets will face a combination of these barriers, which are closely linked to one another. For the past three to four decades, the Kingdom of Saudi Arabia has witnessed an explosion of economic development, which has been brought about by the discovery and commercial exploitation of oil in the 1930s. The traditional societies of the Kingdom transformed into lifestyles similar to those in many developed societies due to the rising market demand in the 1970s ([35] Mubarak, 1999; [42] Sidawi, 2008). [21] Gamboa (2008) stated that Saudi Arabia's cities are the fastest growing cities in the Middle East. This is documented by the tremendous increase of population in Saudi Arabia's main urban centres. Within a period of 42 years (1950-1992), Saudi Arabia's urbanisation level increased markedly from 10 to 75 per cent ([28] Library of Congress, 2011). Cities such as Riyadh expanded in such an exponential manner, bearing both sweet and bitter fruits for Saudi Arabia ([3] Al-Hemaidi, 2001; [21] Gamboa,(2008). According to [10] Bonetti (2009) "The largest and fastest growing building markets are today found in the developing world". This transformation resulted in an urban sprawl of all major cities in Saudi Arabia. Due to a rapidly escalating population, and a high level of economic growth, the Kingdom of Saudi Arabia is experiencing a vigorous infrastructure expansion, especially with respect to residential buildings.

Unfortunately, however, when compared to other countries, the issue of energy efficiency is not generally given serious consideration with regard to Saudi building designs. In addition, the Kingdom of Saudi Arabia is one of the driest regions in the world and is facing serious challenges relating to a rapid growth in water demand. Against such a background this paper argues that sustainable architecture should be actively and urgently pursued in Saudi Arabia. In order to achieve this goal effort should be made by Saudi architects to minimise a building’s water and energy consumption and to do this through the use of climate-responsive designs as well as environmentally friendly renewable energy technologies. While focusing on the Saudi Arabian scenario, the fast-growing development of building construction industry necessitates proper measures to ensure energy-efficiency and environmental health during all the lifecycle stages of buildings. Though this sector contributes substantially to the employment options and economic growth in the Kingdom, it lacks in scientific skills and expertise in employing energy-efficient and ecofriendly construction techniques, materials and structures. Few studies have been reported on energy and environmental issues in the Saudi Arabian building sector. For instance, Fasiuddin and Budaiwi [2] investigated major design and operational parameters for different types of HVAC systems influencing energy consumption with the help of Visual-DOE program. They identified an energy saving potential of 30% by the proper selection and operation of HVAC systems. Meanwhile, Taleb and Sharples [3] focused on the household energy and water consumption practices. A typical residential apartment was considered for the study which identified several design-related faults which contributed to inefficient use of energy and domestic water resources, and recommendations were made accordingly. Alyami and co-workers [4, 5] have made promising contributions towards developing sustainability assessment tool suitable for Saudi Arabian buildings. This paper aim at providing the various lapses for applying susutainability assessment in the Saudi building sector as a rating too. Next, identifying each shareholder and it's various hinderance to our set aim.

1-2 Sustainability status in the Saudi building sector

Generally speaking, sustainability encompasses a blend of environmental, economic and social responsibilities. Given recent environmental and energy concerns, there has been a

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considerable interest in recent years with regard to the concept of sustainable architecture. The main drivers behind promoting sustainable architecture are definitely ecological and energy considerations, as well as some other factors such as health-related concerns and the desire to improve residents’ quality of life. In principle, sustainable buildings relate to the notion of climate-responsive design. This places an emphasis upon natural energy sources and systems with the aim of achieving building comfort through interactions between the dynamic conditions of the building’s environment. For example, the placement of a window in a sustainable building is of the greatest importance as it could provide effective natural light, comfort cooling and ventilation. Such principles are absent in current Saudi buildings, which are heavily dependent on air conditioning that consumes massive amounts of electricity. As a result of poorly designed buildings in Gulf Cooperation Council (GCC) countries, which include Saudi Arabia, nearly 80% of household electricity is used for air conditioning and refrigeration purposes In Saudi Arabia, as a result of a rapid population growth and increased urbanisation, not only is the residential sector booming, but it also constitutes more than half of the country’s energy demand. The design of modern houses in Saudi Arabia is no longer based on the principles of vernacular architecture. Generally speaking, vernacular architecture tends to emphasise the utilisation of local building resources, as well as the use of passive and low-energy strategies that could lead to reducing the need for both air conditioning and lighting requirements. Moreover, it is unfortunate to note that electricity generation in Saudi Arabia is completely dependent on the unsustainable practice of burning fossil fuels, which causes major environmental impacts on air, climate, water and land. In addition, despite the abundant availability of renewable energy sources, the use of sustainable energy technologies, such as solar photovoltaics (PV), is exceptionally rare in the oil-rich Saudi Arabia. Last, but certainly not least, there are no regulations, or compulsory building codes, that incorporate the principles of sustainable architecture, in the country. It has been argued by many scholars that setting a coherent set of these codes and standards is one of the most important and cost-effective ways to promote the widespread of sustainable practices, especially with regard to reducing household energy and water consumption. Last, but certainly not least, there are no regulations, or compulsory building codes, that incorporate the principles of sustainable architecture, in the country. Following the energy crises of the 1970s, such building codes have been widely adopted in developed nations, and more recently in developing countries of Argentina, China and Taiwan. It appears, however, that the sustainable building regulations in some of the countries of the European Union are amongst the most stringent ones. A review of such national codes and building regulations, which is beyond the scope of this current paper, is plentiful in the literature. With regard to our paper, we will be limiting the research to one particular share holders group by quantifying their results from the questionnaires on the reasons why they think; sustainability assessment is not applicable using the analytical hierrachy performance (AHP).

2- Methodology

Since sustainability and the framework to assess building sustainability must be context specific and involve stake holders' participation, this paper adopted an approach mainly concerned with assessing the lacks of sustainability assessment policies, and potential improvements in terms of these barriers in Saudi Arabia building industry. The criteria identified from, and refined in, the qualitative phase by questionnaire were then brought into the quantitative phayse by developing an instrument for the purpose of assigning their relative importance by AHP. A pilot study conducted shortlisted the following barriers; high initial cost (H.I.C), lack of regulation (L.R), Lack of qualified expertise (L.Q.E), Lack of incentives(L.I), Lack of Reliability (L.Re), Lack of prototype(L.P), Lack of Awareness (L.A), Lack of certified contractor(L.C.C) and Lack of manufacturing(L.M).The paper targeted responders that represent all stakeholders in the building construction industry, including suppliers, architects, consultants, property developers and government officials. The questionnaire, in this paper is directed to; Saudi Chamber or Council of Engineer (a society that groups all fields of engineers, which include architecture, civil engineering, urban designers and other fields of engineering) and the municpalities ' Baladiya'.

3- Results and discussions

The selection criteria are weighted by the decision makers and experts based on using pair-wise comparison matrix and the AHP. The experts are asked first to fill out the matrix using the AHP decision making method. This method helps to quantify the relative weights for a given set of criteria with regards to a priorities scale ratio from 1 to 9. The relative weights are calculated based on the pair-wise matrix and the scales provided by experts. A sample of the calculation matrix is presented for one expert in Table 1.1. The sample consists of two main tables. The upper table represents the pair-wise comparison matrix of the selection criteria, and the lower table consists of several significant columns, as follows:

Table 1.1 Pair-wise comparison matrix and computing of the relative weights

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Selection Criteria	High Initial cost	Lack of regulation	Lack of Qualified Expertise	Lack of Incentives	Lack of Reliability	Lack of prototypes	Lack of Awareness	Lack of Certified contract	Lack of manufacturing
High Initial cost	1	0.111	0.143	0.2	0.2	0.111	0.125	0.111	0.143
Lack of regulation	9.009009	1	1.28828829	1.8018018	1.801801802	0.776223776	0.625	0.555	0.776223776
Lack of Qualified Expertise	6.993007	0.77622378	1	1.3986014	1.398601399	0.555	0.625	1	1.144
Lack of Incentives	5	0.555	0.715	1	1	0.555	1.126126126	0.888	1.288288288
Lack of Reliability	5	0.555	0.715	1	1	0.430804196	0.80518018	0.888	1.398601399
Lack of prototypes	9.009009	1.28828829	1.8018018	1.8018018	2.321240159	1	1.126126126	1.6	1.144
Lack of Awareness	8	1.6	1.6	0.888	1.241958042	0.888	1	0.788544	1.450775099
Lack of Certified contractor	9.009009	1.8018018	1.12612613	1.12612613	1.126126126	0.625	1.268160052	1	1.575001575
Lack of manufacturi	6.993007	1.28828829	0.77622378	0.77622378	0.715	0.874125874	0.689286713	0.63492	1

A	B	C	D	E	F
Geometric Mean	**EV wieght**	**Aω**	**λ**	**CI**	**CR**
0.17	0.01	0.12	9.19		
1.26	0.10	0.91	9.58		
1.17	0.09	0.82	9.26		
1.15	0.09	0.74	8.50		
0.98	0.07	0.70	9.35		
1.78	0.14	1.26	9.29		
1.42	0.11	1.00	9.30		
1.45	0.11	1.03	9.33		
1.04	0.08	0.75	9.41		
10.43	0.79		9.25	**0.03**	**0.02**

Column (A) shows the calculation of the geometric mean for the values in the rows in the pair-wise comparison matrix. Column (B) shows the calculation of the relative weights (Eigenvalue) of a criterion which is equal to the geometric mean of that criterion over the sum of the geometric mean for all criteria. Column (C) shows the vector weight for criteria, which is equal to the sum of multiplying the relative weights by the values in each matrix's row. Column (D) represents the value of λmax, calculated by dividing the vector weight by the relative weight of each criterion.

The calculation of the consistency ratio, shown in columns (E) and (F), is calculated by dividing the consistency index value (CI) by the random consistency index value (CR = CI / RI). The CI is calculated as follows: CI = (λmax – n)/ (n -1), while the RI value is obtained from table 1.2 using a size n matrix. Expert is judged to be unacceptable when CR exceeds 0.10, which indicates

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Table 1.2 (R.I) Random Inconsistency Index (Saaty 1980)

RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48
n	1	2	3	4	5	6	7	8	9	10	11	12

inconsistency in the judgment matrix. Some of responses are eliminated due to their high consistency ratio.

Table 1.3 Resulted relative weights for the various selection criteria

Twenty responses were conducted during our survey and only fifteen passed the consistency test, as shown in table 1.3. The relative weights of the selection criteria are computed

Selection Criteria	HIC	LR	LQE	LI	LRe	LP	LA	LCC	LM	Total
1	0.021	0.16	0.111	0.139	0.0752	0.041	0.065	0.133	0.0718	1
2	0.0121	0.094	0.099	0.108	0.069	0.12	0.117	0.108	0.077	1
3	0.0133	0.098	0.105	0.136	0.067	0.074	0.134	0.061	0.153	1
4	0.013	0.013	0.092	0.139	0.067	0.079	0.131	0.061	0.153	1
5	0.013	0.101	0.091	0.1	0.075	0.128	0.107	0.0716	0.119	1
6	0.308	0.053	0.064	0.073	0.052	0.069	0.104	0.061	0.046	1
7	0.012	0.105	0.098	0.112	0.099	0.111	0.097	0.115	0.055	1
8	0.013	0.097	0.099	0.123	0.072	0.106	0.072	0.179	0.074	1
9	0.015	0.101	0.101	0.087	0.074	0.086	0.131	0.060	0.145	1
10	0.012	0.082	0.100	0.115	0.095	0.094	0.107	0.095	0.100	1
11	0.012	0.084	0.100	0.115	0.096	0.097	0.104	0.097	0.097	1
12	0.026	0.214	0.214	0.121	0.153	0.229	0.254	0.220	0.000	1
13	0.029	0.212	0.189	0.087	0.157	0.196	0.325	0.212	0.000	1
14	0.013	0.095	0.089	0.087	0.075	0.135	0.108	0.110	0.079	1
15	0.012	0.097	0.088	0.081	0.091	0.124	0.098	0.100	0.091	1
Median	0.013	0.097	0.099	0.112	0.075	0.106	0.107	0.100	0.079	0.789364
Mean	**0.042**	**0.106**	**0.129**	**0.109**	**0.107**	**0.112**	**0.149**	**0.142**	**0.104**	**1**
Mode	0.013	0.097	0.099	0.139	0.067	0.106	0.107	0.061	0.153	
STDEV	0.069	0.048	0.036	0.021	0.028	0.044	0.063	0.050	0.046	0.405608

for every respondent and the mean, median, mode, and standard deviation are calculated accordingly. The relative weights of the selection criteria are computed based on the mean. The average resulted relative weights are computed as: 4.2 % for HIC, 10.6% for LR, 12.9% for LQE, 10.9% for LI, 10.7% for LRe, 11.2% for LP, 14.9% for LA, 14.2 % for LCC, and 10.4% for LM. Simplied illustration on table 1.3 below

Selection Criteria	HIC	LR	LQE	LI	LRe	LP	LA	LCC	LM
Response percentage	4.20%	10.64%	12.90%	10.85%	10.70%	11.20%	14.90%	14.20%	10.40%

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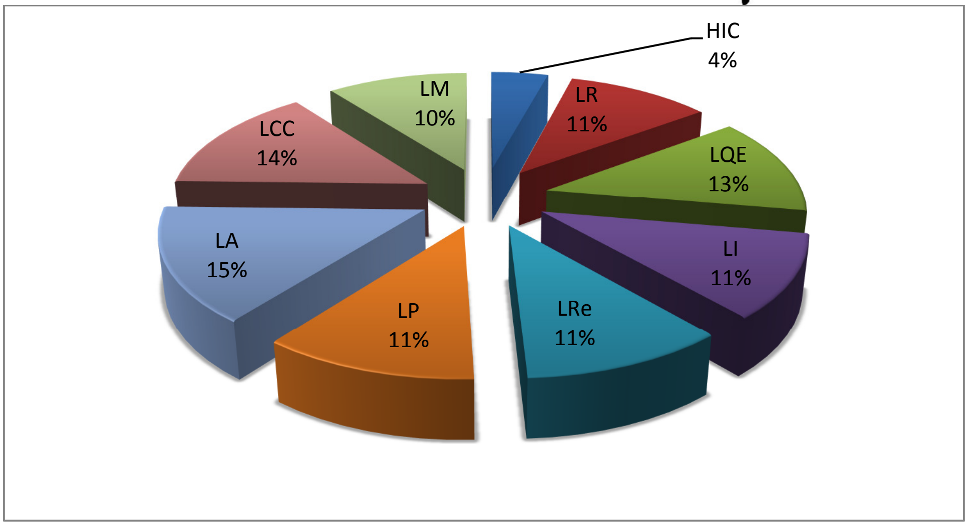

This survey was conducted on several practionners; only few of them responded to the questionnaire base on their knowledge about the issue. These analysis are from educational practionners. The more reason to this catergory of practionners is because, they are the ones training the future, engineers, designers and consultant; thus their knowledge is of future important in this area.

As illustrated in the pie-chart above, the piloted factors; lack of awareness (LA) and Lack of Certified Contractors, recorded a high percentages 15% and 14% respectively. This clearly indicates that most of the practionners are not aware neither are those executing most Project certified.

4- Conclusion

Based on the literature review, this study summarized relevant responses from the piloted factors to why there's lack of sustainbility assessment as a rating tool in the building industry - KSA. According to the analysis of the AHP, the piloted qaulitative factors were being converted to qauntitative. It clearly indicated that, lack of awareness is our major draw back to why there's lack in sustainability application in buildiing projects. The hight initial cost was of respondants least conern as compared to other factors respectively. Nevertheless, to over come the issue of awareness, it is recommended to intergrate it to the media, newpapers, and by also creating short conferences to sensitize the people of sustainability issues and it's benefits to the environement and our building industry.

The limitations of the study are due to the AHP method assigns two factors with quantitative values for comparison, thus it was not easy to compare the attributes of tangible and intangible and some factors may be interdependent in some degree. Finally, the weight score model developed in this study can be used in future studies to evaluate the performance of building Project with sustainability assement feautures to conventional buildings.

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Net Zero Energy Schools: The Cutting Edge of US Net Zero Strategy

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Abstract: *Government and non-government organizations are dictating and supporting the rapid implementation of net zero energy strategies in the US. The Energy Independence and Security Act (EISA) of 2007 sets a national goal to achieve zero-net-energy use for new commercial buildings by 2025. A further goal is to retrofit all pre-2025 buildings to zero-net-energy use by 2050. In California, generally thought to be the US leader in energy policy, the California Energy Commission (2011) developed a policy called the Big Bold Energy Efficiency Strategy (BBEES) in 2010 and revised it in 2011. BBEES calls for all new residential construction in California to be zero net energy 'or equivalent' to zero net energy by 2020; and all new commercial construction in California to be zero net energy 'or equivalent' to zero net energy by 2030 [1]. The implementation of US net zero strategy is being led by new primary and secondary school projects which are serving as testing platforms for measuring the technical and economic success of the net zero concept. This paper will describe and analyze around 20 school projects in different US states, ranging east to west. Schools are good candidates for net-zero energy because they naturally use less energy than other kinds of buildings. However they are an important class of facilities, consuming about 17% of total US non-residential energy.*

Key words, Net zero energy, Energy neutral, K-12 schools

Introduction

Education is of utmost importance for society and the families of which it is comprised. According to the National Center for Education Statistics, more than 55 million students enroll annually in U.S. K-12 schools (below college and university level). In 2013, this figure was around 5.2 million students for private schools and 50.1 million for public schools. These students enroll annually in more than 130,000 schools in U.S. (roughly 75% in public school and 25% in private ones) [2]. A significant amount of research demonstrates that the performance of this population of students is affected by the quality of the physical environment such as appropriate temperature, day lighting, air quality, sound, temperature, etc. Interestingly, improving such factors can also bring energy reduction. Considering that energy expenses are often the second highest costs after personnel salaries, further attention to maximizing the energy efficiency of schools is a sensible goal. Recent reports about the performance of U.S. green schools show that, on average, $100,000 of operating costs can be saved annually per school by using high performance green building strategies [3] [4]. These savings can pay for two new teachers or be spent on supplies like books, computers and other materials and supplies. Furthermore, energy-efficient schools that incorporate new renewable energy technologies can better demonstrat the importance and value of protecting our surrounding environment. As a result, energy-efficient buildings can play a teaching role in illustrating the true impact of building green practices (ASHRAE, 2011).

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The School of the 21st Century

Changes in patterns of life in the late 20th and early 21st century caused new concerns for the educational system. Parents now care far more about the quality of the education under which their children are nurturing. The *School of the 21st Century* (21C School) concept is a community school model that is proposed to meet the pressing need for affordable high quality childcare system to provide an environment that comply with parents working life while ensure their children are learning the materials they need to succeed in their lives [5].

It is obvious that the school building has a significant influence in achieving 21C learning goals. The factory model of the historic schools is now shifting to a model of green construction that utilizes the latest research in high performance green schools. As we are moving forward, the new and existing school buildings are built and retrofitted with the use of recent technologies that make a building more environmental friendly and more energy efficient. Additionally, increasing number of educators and school boards encourage innovative designs and further motivate architects to rethink in a sustainable way. Legislators are also paving the way through allocation of funding to the schools. Introduction of the H.R. 3021 and 3187 ''21st Century High-Performing Public School Facilities Act'' in the year 2007 and 2009 are good examples in the U.S. This Act indicates that the Secretary of Education should provide grants and low-interest loans to local educational agencies for the modernization, renovation, or repair of public early learning, kindergarten, elementary, and secondary educational facilities [6]. Third-party verification organizations are also playing a fruitful role to adjust the school buildings to the 21st Century School goals. The U.S. Green Building Council (USGBC) has created a center for green schools ad their LEED school rating system can measure how a K-12 school facility can support its occupant's health and save resources, energy and money. The Green Building Certification Institute (GBCI), the certification arm of the USGBC, reviews LEED applications and provides feedback on registered projects. This Institute has certified more than 3000 schools and the majority of them have been built at little or no additional cost compared to conventional schools. These green schools, on average, use 32 percent less water and 33 percent less energy than their conventional counterparts, and are able to save an average of $100,000 per year per school on direct operating costs [3] [7].

Energy neutral/net zero energy schools

Energy neutral buildings are a concept that evolved as a cutting-edge practice in the field of sustainable construction. A net zero energy school demonstrates a state-of-the-art achievement in the recent surge for green schools. The net-zero energy school has the same definition as a net zero energy building, that is, it is simply a building that meets its energy demand through renewable energies over the course of a year. The National Renewable Energy Laboratory provides a good definition for net zero energy buildings that can be used for energy neutral schools as well. NREL divides the net zero buildings into four types as shown in Table 1 [8] [9]. Since most schools are situated on a site larger than the building footprint, they are classifired as ZEB B faclities in NREL's definition of a zero energy building. A school can also become net zero energy by purchasing renewable-based energy from the grid (ZEB D category), however, the added value comes when the school is first energy efficient then energy neutral. It should be noted that a school may not be energy-efficient but can be net zero energy by installing as many solar panels as needed on-site or off-site. Therefore, the definition of a net zero energy school should be modified by limiting the source of energy to the project site and setting a maximum limit for the annual energy use intensity (EUI). According to the current best practices in this area, this maximum limit for schools is usually placed between 25 and 35 KBtu/SqFt/Yr, based on geographical location and climate zone.

On average, schools in the U.S. consume around 75 KBtu/SqFt/Yr. The U.S. Department of Energy (DOE) states that nationally K-12 schools spend over $6 billion each year on the energy. DOE indicates that at least 25% reduction in energy consumption can be achieved through smart energy management [10]. The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) in conjunction with The American Institute of Architects AIA, US Green Building Council (USGBC), and DOE have developed a strategy that designed to achieve 50% energy savings for K-12 schools compared to ASHRAE 90.1 2004. This strategy is essentially a path towards net zero energy buildings that can be used in the early design phase of new schools [11]. In general, for a school to become net-zero, the energy consumption must be cut in half compared to a conventional school.

NREL definitions of net zero energy buildings	
ZEB A	utilizing renewable energy strategies within building footprint
ZEB B	utilizing renewable energy strategies within the property site
ZEB C	utilizing renewable energy within the property site but from off-site resources
ZEB D	importing renewable energy that is generated outside property lines

Table 1 *Source: Torcellini et al. (2006)*

Net zero energy ready schools

Near zero energy schools and net zero ready schools are the schools that are very close to being net zero energy, or they are designed to become net zero by implementing or adding renewable sources of energy in the future. In 2007, the European Council for Energy Efficient Economy set a target in its Article 9 of Energy Performance of Buildings Directive for achieving “nearly-zero energy buildings” for all new buildings in 2020 [12]. This nearly zero energy building term was defined as a building with very good energy performance. The very-low quantity of energy needed should be covered from renewable source of energy produced on-site or nearby. This is a suitable definition for near zero energy schools. However, an important question here is how close they are to being energy neutral. The near zero energy term covers a wide range of low energy buildings and some may outperform existing zero energy buildings in their energy consumption while others are far removed from best practices. This ambiguity can be attributed to the difficulty in ranking projects due to the wide criteria involved in energy performance of a property relative to its peers, taking into account the climate, weather, and business activities. Regarding schools, the Energy Star rating system adjusts and normalizes its score based on school building size, number of

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computers and refrigerators, schedule of school on weekends and summer, energy used for cooking, type of the school (for example high school), dominant climate and heating and cooling degree days, as well as the percent of the building that is heated and cooled [13]. The current sustainable design practices in the field of green schools have led to the design and creation of many net zero energy ready K-12 schools in US. These energy efficient schools are either designed as a net zero capable school that are waiting for funding for the installation of solar panels in the future, or they have a very close performance to an energy neutral building. Schools such as Pflugerville Elementary School in Pflugerville, Texas and the Richard J. Lee Elementary School in Dallas, Texas are good examples of NZE-ready schools [14]. These under-construction schools are supposed to have a great energy performance but they are not energy neutral mainly due to the high cost of renewable energy systems. Lee Elementary School may be net zero energy depending on the decision of its board members to sell district bonds to purchase the required solar panels [15].

US outstanding net zero energy school projects

School facilities are known to have higher potential for adopting net zero strategies and benefiting from sustainable design compared to other building types. Several items (such as seasonal occupation and partial daily use, large sites and roofs, community owned and educational land use that ends up in less energy consumption) make schools a suitable target for accomplishing energy neutral goals [16]. There are over 20 net zero energy schools in the U.S and some more under construction. The majority of them are fitted in the “ZEB B” NREL definition as a building that utilizes renewable energy within the property site. These state-of-the-art cases were claimed or designed to be zero energy. However, most of them are not a verified net zero energy facility with a third party verification system like Living Building Challenge (LBC). Undoubtedly, these buildings are super-energy-efficient and can treat as a role model for other school projects.

The schools in the following tables are collected through authentic websites, case studies, and published research papers. Some net zero energy schools that are below 10,000 square feet (929 m^2) like Prairie Hill Learning Center in Roca, Nebraska; Watkinson School in Hartford, Connecticut; Bertschi School Science Wing in Seattle, Washington; Hood River Middle School in Hood River, Oregon; Lenawee Intermediate School in Adrian Township, Michigan, are excluded from the table due to their small size. Net zero energy educational facilities like labs, university buildings, and administration buildings are not included in this study as well, since K-12 schools are the center of attention here. Energy Lab at Hawaii Preparatory Academy; Lenawee Intermediate School District Center for a Sustainable Future; and George LeyVa Middle School Administration Building are some examples.

No.	Name	Year Completed	Location	Area	# Students	Annual Site EUI
1	**Putney School Field House**	2009	Putney, Vermont	16,800ft² 1,560m²	215	11 kBtu/ft² 125kW/m²

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2	**Marin County Day School**	2010	Corte Madera, California	33,000ft² 3,065m²	540	25 kBtu/ft² 285kW/m²
3	**Hayes Freedom High School**	2010	Camas, Washington	20,500ft² 1900m²	153	23 kBtu/ft² 260kW/m²
4	**Richardsville Elementary**	2010	Bowling Green, Kentucky	20,500ft² 1,900m²	600	18 kBtu/ft² 205kW/m²
5	**Sangre de Cristo**	2011	Mosca, Colorado	80,000ft² 7,430m²	400	22 kBtu/ft² 250kW/m²
6	**Kiowa County School**	2010	Greensburg, Kansas	132,000ft² 12,260m²	370	29 kBtu/ft² 330kW/m²
7	**Evie Garrett Dennis School**	2010	Denver, Colorado	186,500ft² 17,320 m²	1278	26kBtu/ft² 295kW/m²
8	**Turkey Foot Middle School**	2010	Edgewood, Kentucky	133,000ft² 12,350 m²	1000	14kBtu/ft² 160kW/m²
9	**Lady Bird Johnson**	2011	Irving, Texas	152,000ft² 14,120 m²	1000	23kBtu/ft² 260kW/m²
10	**Colonel Smith Middle School**	2011	Fort Huachuca, Arizona	88,693ft² 8,240m²	350	15kBtu/ft² 170kW/m²
11	**Locust Trace AgriScience**	2011	Lexington, Kentucky	47,088ft² 4,375m²	250	/
12	**Centennial School**	2011	Centennial, Colorado	60,000ft² 5,575m²	221	14kBtu/ft² 160kW/m²
13	**Sandy Grove Middle School**	2013	Hoke County, North Carolina	75,930ft² 7,054m²	650	25.6kBtu/ft² 290kW/m²
14	**East Bay MET School**	2014	New Port, Rhode Island	16,800ft² 1,560m²	180	/
15	**Blackford School**	2014	San Jose, California	/	/	/
16	**P.S. 62 School**	to be built	Staten Island, New York	68,068ft² 6,320m²	444	34 kBtu/ft² 390kW/m²
17	**Cambridge MA - MLK School**	to be built	Cambridge, Massachusetts	169,000ft² 15,700m²	740	30 kBtu/ft² 340kW/m²
18	**New Century Elem-Sch**	to be built	Raleigh, North Carolina	109,758ft² 10,200m²	920	/
19	**Richard J. Lee Elem-Sch**	to be built	Irving, Texas	95,600ft² 8,900m²	/	29 kBtu/ft² 330kW/m²
20	**Arlington Elem-Sch**	to be built	Arlington, Virginia	98,000ft² 9,000m²	630	23kBtu/ft² 2600kW/m²

Table 2, US net zero energy schools

Figure 1 shows the location of these schools base on their column number. Almost all of them are located in the climate zone 3 to 6. Climate zones 3 and 4 have the most existing NZE-schools.

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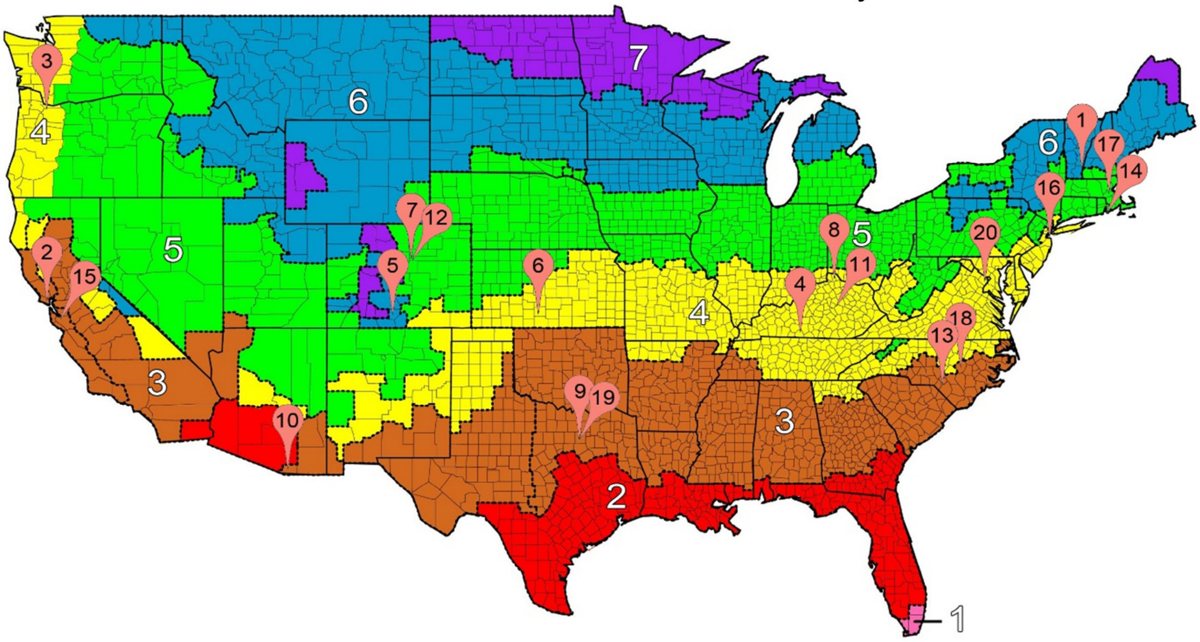

Figure 1, US climate zones, Source Climate Zones for U.S. locations from Figure B-1 of ASHRAE 90.1-07

Climate Zone	No. of NZE-schools
1	
2	
3	7
4	7
5	4
6	2
7	
8	

Table 3 # of US NZE-schools in each zone

1 Very Hot – Humid / Dry
2 Hot – Humid / Dry
3 Warm – Humid / Dry / Marine
4 Mixed – Humid / Dry / Marine
5 Cool – Humid / Dry / Marine
6 Cold – Humid / Dry
7 Very Cold

All of these schools are benefiting from three types of strategies that are renewable energy strategies, energy efficient strategies, and educational strategies. These strategies are shown in brief in the table 4.

Photovoltaic (KW)	Wind Turbines	Optimized Orientation	Multi-Story Building	Daylighting	Geo-exchange	Solar Thermal	High Performance Envelope	High Performance Lighting	High Performance HVAC	Automated Sensors	Energy Monitoring

1	**Putney School Field House**	37		☑		☑		☑	☑		☑	☑	
2	**Marin County Day School**	95		☑		☑			☑				☑
3	**Hayes Freedom High-Sch**	-		☑		☑			☑				
4	**Richardsville ES**	394			☑		☑	☑	☑	☑	☑		☑
5	**Sangre de Cristo PK-12**	-		☑			☑		☑			☑	☑
*6	**Kiowa County School**			☑	☑	☑	☑	☑	☑				
7	**Evie Garrett Dennis Pre-K12**	288		☑	☑	☑	☑			☑	☑	☑	
8	**Turkey Foot Middle School**	443					☑		☑		☑	☑	
9	**Lady Bird Johnson Mid-Sch**	550	☑	☑		☑	☑		☑	☑	☑	☑	☑
10	**Colonel Smith Mid-Sch**	-	☑			☑		☑		☑	☑	☑	☑
11	**Locust Trace AgriScience**	175				☑	☑	☑	☑	☑	☑		☑
12	**Centennial PK-12 School**	-				☑		☑	☑		☑		
13	**Sandy Grove Mid-Sch**	590			-		☑		☑	☑	☑		☑
14	**East Bay MET School**	100		-	☑	☑	☑	☑	☑	☑			
15	**Blackford School**	-	-	-	-	-	-	-	-	-	-	-	-
16	**New York P.S. 62 School**	-		☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
17	**Cambridge MA - MLK**	282		☑	☑				☑			☑	
18	**New Century Elem-Sch**	856					☑	☑	☑	☑	☑	☑	
19	**Richard J. Lee Elem-Sch**	-	☑	-	☑	☑	☑	☑	☑				
20	**Arlington Elem-Sch**	500		-	☑	☑	☑		☑	☑		-	-

Table 4, US NZE-school's energy strategies
**Kiowa County K-12 School is a ZEB D building that means it uses renewable energy generated off site.*

Conclusion

More than 20% of the US population spend their time in school facilities as students, staff and other users of the buildings. These educational facilities affect not only this population, but also the communities and the local environment. According to the USGBC Center for Green Schools "The environmental effects of school facilities are a function of where schools are sited, their size, the sustainability of their design and the efficiency of their operation and use."[3] The development of energy self-sufficient schools is expanding parallel to the growth in environmental concerns. This progress in sustainable schools has been made possible through the advancement in new construction technologies and improvement in the renewable energy capturing techniques, as well as energy efficient devices. Successful existing net zero energy schools in US, such as Lady Bird Johnson Middle School, have increased the popularity of NZE-schools and prove the potential of this concept at larger scale. Energy policies of several states in the US and some countries around the globe have set net zero energy targets for the new building projects in the near future. In our perspective, school facilities are a very suitable starting point for these energy targets. Schools not only can significantly reduce energy costs, but can also play a role in teaching young students about energy efficient strategies.

More research needs to occur regarding the development of the optimal school energy policies. Although there are many successful existing NZE-school projects around the world, there is a shortage in the amount of prepared instruction and guidelines to achieve such school projects easily and economically. The collaboration of academic research in this area with the applied knowledge of the existing project engineers, architects, and managers, can play a significant role for the success of future projects. Economies of scale would reduce the higher costs of planning and design and a well-organized guideline for each climate zone would be very helpful. As a case in point, Florida Net Zero Energy School Initiative (FNZESI) was established in the Powell Center for Construction & Environment at University of Florida to produce a guideline for the NZE-schools in the hot humid climate zone of the U.S. The emergence of such initiative and working groups is a step closer to the future energy targets.

Financial expenditures to implement energy efficient strategies have not been discussed in this paper. Further studies should be undertaken to define an optimal balance between the higher upfront costs and obtained EUI, as well as the return on investment. “Net Zero” is no longer new to construction industry and schools are serving as test platforms for implementing technical and financial strategies. We recommend more detailed research on integrating energy and economic policies for schools in Florida which can motivate many other schools to achieve net zero energy status.

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Characterizing building renovations in the residential sector in Victoria, Australia

Abstract: *The Victorian Building Authority (VBA) is the organization responsible for building regulations and standards in the State of Victoria, Australia. The VBA works closely with the Australian Building Codes Board, the national body responsible for the National Construction Code (NCC), dealing with energy and water efficiency in buildings. This paper presents Part 1 of a five-part study undertaken to characterize the nature of the market for home additions and alterations in the State of Victoria, Australia and understand how energy efficiency provisions under the building code are interpreted and applied in practice.*

The overall research method involved identifying and assessing building permit data for a significant sample of dwellings in selected regions of metropolitan Melbourne and undertaking energy assessments of these dwellings complemented with surveys with selected building practitioners. The results of Part 1 provide a general understanding of alignment between regulatory practices and intended building construction outcomes.

Key words: Alterations, additions, renovations, residential, Australia, energy efficiency

Background

Energy use world wide is on the increase [1]. New houses need energy for construction. In Australia there are about eight million homes, responsible for approximately 13 per cent of Australia's energy use and 10 per cent of its greenhouse gas emissions [2]. In Victoria, energy use in the residential sector consumes about a fifth of the state's total energy supply [3]. The energy use is directly attributable to the types of houses constructed and the energy used to heat and cool these homes, in addition to the energy use of appliances within the home [4]. Renovation of existing homes offers an opportunity for the current building stock to improve with regard to energy efficiency as *existing* houses make up over 95% of total housing stock. Furthermore construction activity in the renovation sector, though variable, is comparable in magnitude with the number of building permits issued each year for new homes in Victoria [5].

The Victorian Building Authority (VBA) is the regulator of the building, plumbing and architecture industries in this Australian state, providing domestic building consumer protection and ensuring the safety, liveability and sustainability of the built environment. VBA is enabled under a number of Acts and Regulations to undertake its regulatory role [6].

The National Construction Code is administered by the Australian Building Codes Board (ABCB). The Code 'addresses issues relating to safety, health, amenity and sustainability in the design and performance of buildings through the National Construction Code (NCC) Series, and the development of effective regulatory systems and appropriate non-regulatory solutions' [7]. Minimum technical design and construction standards for both building and plumbing work are defined in the NCC. Each Australian State and Territory mandates the NCC as a regulatory requirement for that jurisdiction under its own specific building or planning legislation.

Under the umbrella of the National Strategy for Energy Efficiency (NSEE) across the built environment, in 2010, the NCC increased minimum standards. For the residential sector, the standard moved from 5 to 6 Stars, making both new and existing homes more stringent in energy use. This Star Rating system is a national scheme for determining the energy efficiency of residential buildings at the design stage using a number of accredited software rating tools. The new standards, which came into effect on 1 May 2011 [8] [9], also included efficiency requirements for hot water systems and lighting in addition to the building envelope.

This paper focuses on renovation characteristics of houses in Victoria. Following a brief summary of the current state of play with respect to housing retrofits, the paper presents the aim, method of study, findings and discussions with conclusions at the end.

State of play

Achieving energy efficient built environments have been studied at both the building scale and the scale of precincts and cities nationally and globally. Retrofitting involves not just modifying what exists from a technological perspective, but also from a social perspective where behaviours and choices shape daily practices.

In Australia, research focusing on policy implications, energy use in households, house size, economic cost and sustainability features, and the impact of climate of new and existing buildings have been presented [10-15]. A recently released report for the federal Department of Industry [16] to check if the 5 Star standard has reduced energy use found significantly reduced energy use in winter but higher cooling loads in summer. Houses rated 5 Star or above cost less to build up front. However this research addresses new houses; a gap remains in understanding the profile of renovations.

Information regarding renovations, particularly, pertaining to size, type, value and building envelope elements, services and other environmental features were not available and therefore, difficult to interpret how energy efficiency is understood and interpreted. The VBA needs such information to effectively carry out its regulatory functions effectively. Hence this study to understand the profile of home renovations was undertaken so as to determine the best way to maximise energy efficiency outcomes.

Aim of this study

The primary aim of this study was to understand how NCC energy provisions applying to home alterations and additions are being interpreted and implemented in the market. Subsidiary aims were to identify current trends and characterise the typical home alterations and additions.

Method

The overall study included 5 parts. Data collection formed Part 1 of this study and this paper focuses on attendant data collection and subsequent analysis. The other parts of the study (2-5) involved surveys of architects and registered building surveyors (Parts 2 and 3). Part 4 was

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an audit of a selected sample of plans. Part 5 focused on development of energy effiicient floor plans of this selected sample of alterations and additions to provide guidance to the industry and consumers.

Part 1 forms the focus of this paper. A sample of 200 dwellings which underwent renovation/alterations/additions were selected. This sample was drawn from building permit applications required by law to be lodged with local Municipal Councils. The Councils selected were the top four local government areas from the inner Melbourne metropolitan area having the highest number of home renovations and alterations. The cases were selected based on permit applications lodged between January 2009 to November 2011, so as to capture the period since the 5 star standard was first introduced and mandated across all jurisdictions in Australia.

Using data provided by Pulse, a database collated by the Building Commission (now the VBA) local government areas in inner Melbourne with the highest number of home alterations and additions were identified. Fifteen inner city Melbourne Councils; Melbourne, Hobsons Bay, Port Phillip, Maribyrnong, Moonee Valley, Banyule, Darebin, Moreland, Yarra, Monash, Whitehorse, Boroondara, Glen Eira, Stonnington and Bayside were identified. The building types considered were detached houses—covered under Class 1a (i) under the NCC. Row houses, townhouses, villas and other such combinations were not considered, making up other parts of NCC Class 1. The Pulse data of additions/alterations undertaken showed Boorandara, Whitehorse, Moreland and Darebin as being the top Councils having the highest number of permit data for additions and alterations. All Councils except Whitehorse council participated in the study.

To further filter the data, complete information about the alterations/additions were sought rather than data where additions/alterations included re-blocking or re-stumping of the houses. Where no floor or allotment area were provided, these cases were eliminated. Thus, data that showed clear alterations/additions were selected. In addition, where allotment and floor areas were clearly provided, cost about or in excess of $100,000 from suburbs comprising the local government areas already chosen were selected.

A template for recoding the data was developed focusing on a three year period. It included house type and style, description of the alterations/additions, any demolition works, alterations/additions, details of construction, floor area of the exisiting house, floor area of the renovation/alterations, floor area of proposed house, energy rating report, insulation details as per the energy rating report, consistency between the documentation and the energy rating reports (particularly between the R values), passive design features, heritage signficance including heritage overlays and other significant features such as any building surveyor dispensations, and additions of pools/spas, solar panels and solar hot water systems. Data analysis provided information pertaining to characterising home alterations and additions, providing details such as size, cost, types of renovation, materials of construction used in the renovation use and allocation space in the renovations.

In total, 1200 building permits were examined—between 300-500 were considered per council. Within each council, suburban distributions of the permits were considered, as this provided a profile of local building trends in that municipality. From the 1200 permits, data was further filtered to arrive at the total of 200 permits for subsequent detailed analyses. Around 70 permits from each council were further analysed.

Findings and discussions

Data collected was analysed to provide information and understanding regarding four main parts for characterising home renovations/alterations: profile of domestic building renovations by municipality, characterisation of the trends for renovations, construction types and materials used, and floor area of renovations.

Profile of building renovations by municipality: It was found that the median cost of additions/alterations ranged from $200,000-$150,000. The highest median costs of renovations in Boroondara were $214,000, largely in the suburbs of Hawthorn and Kew in the City of Boroondara. The median cost in the City of Moreland was $140,000. The median cost in the City of Darebin was $166,000. The largest number of renovations occured in Kew, Camberwell and Hawthorn in the City of Boroondara, Coburg in Moreland and Northcote in Darebin. The cost of renovations sampled provided the median reported cost of works at $267,810 average reported cost of works at $351,870 and maximum reported cost of works at $4,182,750.

Characterisation of trends for renovations: The architectural styles of homes that were renovated were predominantly (85%) Post-war, Californian bungalow and Edwardian. There were no differences found between the renovation trends between homes with and those without Planning Heritage controls in place.

Demolition works were typically undertaken as part of renovations. Outdoor structures such as carports/garages, sheds, verandahs/pergolas and decks were typically demolished, especially if they were at the back of the house. Some demolitions included breaking down internal masonry walls, ceiling and roof structures to reconfigure and expand existing spaces and provide a better utilitarian value to these spaces.

Upper building storeys were often affected. Most of the works were ground level additions and alterations (48%), with some adding to the upper storey (47%). One percent of the new building works went up to 3 storeys and the remaining (4%) was not stated.

Trends in the types of renovations showed largely ground floor internal refurbishments and ground floor additions (42%); and ground floor internal refurbishments, ground floor additions and new first floor additions (25%). Noteworthy were also renovations restricted only to ground floor additions (9%) and ground floor internal refurbishment with new first floor addition (6%). More than 80% of the renovations included ground floor additions and internal refurbishments. Internal refurbishments indicate refurbishments to both ground and existing first floors, whereas ground floor additions are only restricted to the ground floor.

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Refurbishments of existing floor areas include adding robes in existing bedrooms, refurbishments to existing bathrooms, creating ensuites, conversion of existing kitchen into bathrooms/laundry, creating new open plan kitchen/living/dining areas and converting bedrooms into sitting/lounge/rumpus areas.

First floor additions included additions of bedrooms, addition of bathrooms and ensuites, and addition of walk-in robes. First floor additions typically included additions to floor area to the existing first floor and adding a new first floor to a single storey house. Thirty percent of first floor additions also include study areas and lounge/lobby or retreating areas, usually adjacent to or opening onto a stairway. In addition, one, two or three bedrooms were added to the first floor additions. About a third of the samples included addition of 2 bedrooms, and about a quarter, 1 or 3 bedrooms. Eleven per cent of the sample added 4 bedrooms and a very small percentage (1%) added 5 bedrooms. Most of the home renovations involved demolishing rear kitchen, laundry, and bathrooms—replaced with large new open plan combined kitchen/living/dining areas, laundries and bathroom/WC facilities. Most homes had increased numbers of bedrooms post renovation. Where renovations involved first floor additions, bedrooms tended to be added to the first floor with ground floor areas demolished or reassigned to other space functions.

Almost all homes sampled had some sort of outdoor work undertaken. Typically, addition of decks, verandahs, pergolas, alfresco dining, BBQ areas, carports, garages, sheds and storerooms were commonly observed (approx 80%). Unsurprisingly, open areas such as decks and verandahs were accessed and associated with large open plan kitchen/living/dining areas. This trend can be linked to better connections between indoor and outdoor living spaces. As the median floor areas of houses were 500 sq m, with existing median floor areas being 150 sq m, the trends in the renovations hinted to potentially enhancing indoor and outdoor areas.

Construction types and materials used: Through the building levy database maintained by the VBA (as part of its administrative functions) and from building permit drawings, it was found there were consistencies in the types of materials used for construction of the roofs, walls and floors, although the actual figures varied. Levy data showed that roof cladding was matched to the existing structure, comprising mainly metal (31%) or tile (31%). The remaining comprised of 2% aluminium, concrete/slate 1% and 34% not reported.

Construction drawing data showed that 42% was compiled of tiles and 55% was metal. Wall constructions also matched those of the existing walls; they were mainly weatherboard (30%) or brick veneer (24%), with 35% not reported. Construction data through drawings showed that weatherboard dominated at 42% and brick veneer was 29%. Levy data showed that new building frames were mainly brick veneer (65%); no metal frames were reported, but the remaining 35% were not reported. Floors varied from timber floors on concrete stumps and concrete slab on ground. Construction data showed that elevated timber floors represented 62% of the sample set and concrete slab on ground some 32%.

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Floor area of renovations: Regulatory requirements (Regulation 608, 2006) [9] specify that if the proposed alteration is greater than 50% of the original volume, the entire building needs to meet the energy efficiency requirements as stated in the NCC. The Relevant Building Surveyor (RBS) has discretion to vary this.

The calculation of the volume of the house was to ascertain the trends in the size (volume) of alterations, floor area changes and therefore, how the discretions and dispensations are being understood and determined by the RBS. Since the volumes were not provided in the levy data or the drawings *per se*, floor areas were used as a starting point and the volume was determined as an approximation (considering the plans and elevations). Of the total number of homes sampled, if was found that 90% of the homes had new floor areas over 25% of the existing floor area, 70% of the homes had alterations comprising more than 50% volume of the existing buildings, and of the cases that had alterations greater than 50% of the volume of the existing building, 15% had documentation for special dispensation where there were no modifications required to the existing structure, thereby not having to meet the energy efficienc requirement set by the NCC.

Conclusions

The magnitude of residential building activity in Victoria, as represented by building permits, is comparable for the renovation and new home sectors. This provides a significant opportunity to improve the existing building stock's energy performance. Since average value of renovation works was almost $352,000 these are quite significant construction projects requiring effective design and construction controls. No constraint on the design of home alterations was observed as a consequence of Planning Heritage Controls (overlays) applying to some of the sampled properties. Construction techniques used for renovation and alteration works were broadly in line with those found in the existing housing stock. The regulatory requirement that a renovation exceeding 50% of the prior building volume means that the whole building must comply with current Code energy standards was not found to inhibit the size of home alterations and additions. More detailed analysis of design techniques and regulatory control issues will be needed in order to make this study of the residential property sector truly useful for policy and regulatory development purposes.

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Sustainable construction: Singapore's journey towards zero landfill

Speakers:
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Abstract: *With a land area of 716 km^2 housing a population of 5.31 million, Singapore is a resource-challenged city-state with limited land and natural resources. It is hence critical for us to focus on sustainable development. With this as the backdrop, the Sustainable Singapore Blueprint was launched in 2009 to address these challenges.*

Sustainable Construction (SC) has a big part to play, given the amount of natural resources the building sector consumes. As the regulatory authority of the built environment, the Building & Construction Authority (BCA), plays a leading role, working with our stakeholders to champion SC's policies and best practices. The paper outlines a number of key initiatives to drive SC adoption to meet our long term objective towards zero landfill for the building sector.

Keywords: resources, sustainable construction, policies, best practices, zero landfill

Introduction

As a resource-challenged city-state, Singapore understands the need to use resources efficiently. For this reason, the Inter-Ministerial Committee on Sustainable Development (IMCSD) launched the Sustainable Singapore Blueprint in 2009 with resource efficiency as one of its key objectives.

The building sector consumes a significant amount of natural resources as well as generates considerable wastes from construction and demolition activities each year. Concrete waste which constitutes the bulk of the 1.0 to 1.5 million tons of construction and demolition (C&D) waste generated annually can be potentially converted to higher-value materials for various building and construction works. Other waste streams include copper slag with about 0.2 to 0.4 million tons generated annually.

As Singapore's regulatory authority of the built environment, Building & Construction Authority (BCA) has a leading role to play. BCA adopts a life-cycle approach that looks at the efficient use of building materials at the design stage of the development, secures a higher quality of materials salvaged at the demolition stage, promotes closed-loop recycling of building materials and regulates waste flow to our landfill.

To this end, BCA worked with various stakeholders of the sustainable construction (SC) value chain to develop and roll out the following schemes.

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Schemes to Support SC

These include incentives such as the Sustainable Construction Capability Development Fund (SC Fund), the SC Score under BCA's Green Mark (GM) Scheme, up-cycling initiative and demolition protocol.

The Sustainable Construction Capability Development Fund (SC Fund)
The $15 million SC Fund was set up in 2010 to build up capabilities in recycling of C&D waste and to encourage industry stakeholders in adopting SC materials, practices and technologies for construction, with the eventual aim to steer the industry towards self-sustenance in the demand and supply of SC materials.

BCA's Green Mark (GM) Scheme
This is a green building rating tool launched in 2005 to drive Singapore's construction industry towards more environment-friendly buildings. It is a key supporting lever to promote the adoption of SC initiatives. Developers applying for higher-tiered awards ($Gold^{Plus}$ and Platinum awards) are required to achieve certain SC proficiency levels, either through using recycled materials or through well-thought-out designs to use concrete efficiently in their building projects, or both.

Up-cycling Initiative
In order to conserve precious natural resources such as granite for structural building works, BCA started an up-cycling initiative to channel the concrete waste usage from lower-value applications such as road works to building works. It involves processing concrete waste into recycled concrete aggregates (RCA) to replace granite aggregates in structural concrete used for building works. At the same time, BCA is also exploring the potential use of alternative waste materials to replace concrete waste for lower-value and other civil engineering applications.

Demolition Protocol
This is a set of procedures to help contractors better plan their demolition process to maximise recovery of potential wastes for reuse and recycling, thus diverting wastes going to the landfill. The procedures consist of three main components, namely (1) pre-demolition audit to identify potential materials to be recovered, (2) sequential demolition for recovery of better quality demolition waste, and lastly (3) on-site sorting where the contractors follow a waste management schedule that complies with requirements of relevant authorities for sorting, processing, recovery and disposal of demolished materials.

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The protocol is now being incorporated as part of a Singapore Standard, SS 557 developed by BCA in collaboration with SPRING in 2010.

Public-Private Partnership

Our journey towards zero landfill requires concerted effort from both the public and private sector. With the SC policies and initiatives in place, BCA collaborated with industry stakeholders to push the boundaries of recycling and up-cycling of concrete waste by using these materials for structural applications in actual building projects.

<u>Samwoh Eco-Green Building</u>
Samwoh Eco-Green Building is the first building in the region to use up to 100% RCA in structural concrete works. It has effectively demonstrated the feasibility of using high percentage of RCA in structural concrete and further boosts the confidence of the industry in using recycled materials for building works.

<u>Tampines Concourse</u>
The extensive use of recycled materials in Tampines Concourse exemplified green building construction. 10% washed copper slag (WCS) and 20% ground granulated blast furnace slag (GGBS) were used for primary structures including all the columns, walls and beams; while 30% WCS, 20% GGBS and 20% recycled aggregates were used for non-structural components such as apron drains and footpaths.

<u>GAIA Condominium</u>
GAIA condominium is the first high-rise residential development to adopt recycled materials in structural concrete elements. 20% RCA, 10% GGBS and 10% WCS were used for the primary structures. This project reinforced the feasibility of using recycled materials in structural applications and further encouraged replication in other residential projects.

The successful implementation of these demonstration projects resulted in the revision of our building codes to expand the use of RCA in structural concrete from 10% to 20% (Higher dosages would be considered on a case-by-case basis). Likewise for WCS, up to 10% is allowed for use in structural concrete with higher dosages considered case-by-case.

From Recycling To Focus On Design

Thus far, the industry stakeholders and professionals have responded very positively to the downstream recycling efforts in the building's life-cycle. However, upstream efforts which

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emphasize on the design stage of the life-cycle are still rather lacking. It is thus essential to educate the industry and raise awareness on the importance of adopting a green mindset for building developments – To design with 'Green' intent. Normally when a building is designed more efficiently, better sustainability indicators such as lower Concrete Usage Index (CUI) values can be achieved without compromising on construction safety and productivity. This would be explained in greater detail in the following paragraphs.

Concrete Usage Index (CUI)

To measure the use of concrete in building projects BCA worked with the industry and other stakeholders to formulate an index unique only to Singapore, known as the CUI. The index is defined by the volume of concrete needed to cast a square metre of constructed floor area or CFA (m^3/m^2), for superstructures including both structural and non-structural elements.

CUI allows consultants to compare the amount of concrete used for various design options. Consultants will be able to achieve greater resource efficiency by fine-tuning their building designs. For instance if a typical development has a CUI of 0.6, by reducing it to 0.5 by means of designing for less concrete partition walls, about 16% concrete savings can be achieved already for every square metre of constructed floor area. Reduced concrete translates to lesser natural aggregates used for construction and also lesser demolition/ concrete waste generated at the end of the building's service life.

To further recognise building owners' green efforts, an additional bonus point will be awarded to the overall GM score for disclosing the CUI of their new development.

The following two GM Platinum projects will illustrate how sustainability is achieved when buildings are designed with 'Green' intent.

ITE College West

The 9.54ha 'ITE College West' campus achieved a good CUI of 0.42. A combination of precast hollow-core slabs and pre-stressed flat slabs construction were adopted instead of a beam-slab structural system. The absence of beams also allowed for the design of lower storey heights resulting in a significant reduction of concrete as well as steel usage.

Hundred Trees Condominium

The 396-unit private residential development ‘Hundred Trees Condominium’ achieves a good CUI of 0.42. This is made possible through the use of Cobiax[1] system which contributed to a reduction of about 800m^3 of concrete.

Appropriate design tools to facilitate the computation and design of low-CUI buildings are critical and essential in order to encourage industry adoption. BIM has been identified as the game-changing technology to improve productivity and also promote a greater level of integration across various disciplines over the entire construction value chain.

Riding On BIM Wave

In November 2010, BCA formulated a BIM Roadmap and set a target to have 80% of the construction industry use BIM for planning and design by end 2015. To encourage more stakeholders to consciously keep track of the concrete usage in building developments, BCA is working with potential software developers and the industry to develop add-on tools on BIM platforms to obtain CUI values automatically from the BIM models. This will replace manual CUI calculation which would otherwise take 1 week or more.

Conclusion

SC is critical in helping Singapore conserve and use limited natural resources effciently. As the regulatory authority for the building sector, BCA plays the leading role to drive the adoption of SC practices by using the life-cycle approach, with a focus on Recycling / Use of recycled materials and sustainability-focused design approach for buildings.

Our downstream recycling efforts have started to make an impact on the landfill by channelling construction waste away from it to higher-value applications such as structural concrete for building works. But more importantly, we will need to institutionalise the concept of ‘design with ‘Green’ intent’ targeting at upstream efforts so as to achieve greater resource efficiency.

With the SC policies and initiatives now in place, BCA is confident that the building sector will embark on this journey to achieve sustainability and help meet our long term objective of zero landfill in time to come.

[1] The Cobiax technology helps to optimise the overall material effi ciency through the positioning of hollow void formers modules within concrete slabs which reduced unnecessary dead load in the concrete slab of the structure. About 25% concrete savings for the floor slabs could be achieved using the Cobiax system.

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Session 140:

How does energy efficiency affect different residential models?

Chairperson:

Todd, Joel Ann
Environmental Consultant

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Estimation of city-scale impact of new Japanese energy saving standard for residential building by energy end-use simulation

Speakers:
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Abstract: *The purpose of this paper is to evaluate the quantitative energy conservation effects of the new Japanese energy saving standard by using city-scale energy end-use simulation model developed by the authors. This standard evaluates the energy consumption of a residential building by adopting various kinds of energy saving technologies, such as heat pump water heater, cogeneration system, photovoltaic power generation system, and high-efficiency air conditioners. Therefore, many options are available to achieve this standard, and it is difficult to evaluate the city-scale energy saving effects by the standard.*

First, combinations of technologies that achieve the 2013 standard are examined. Next, our simulation model estimates the city-scale impact of the 2013 standard on residential energy consumption in Osaka Prefecture. The change of the electricity load curve by implementing the standard is also discussed.

Energy saving standard, Residential energy consumption, City-scale energy end-use simulation, Household category distribution

Introduction

To decrease the energy consumption and greenhouse gas emission in the residential sector, it is important to implement appropriate energy saving standards for residential buildings. In the design stage, quantitative evaluation of the energy saving effects of such standards on the city- or country-scale is indispensable.

In the past, Japanese energy saving standards for residential buildings considered only building insulation. This standard was revised in 2013 and an evaluation of annual primary energy consumption was added [1]. The new standard evaluates the adoptions of various kinds of energy saving technologies such as heat pump water heater, cogeneration system, photovoltaic power generation system, and high-efficiency air conditioners. Since many such options are available to adapt to this standard, it is difficult to evaluate the city-scale energy saving effects by implementing the standard.

Because the standard is only for the energy efficiency of residential buildings and equipments, achieving the 2013 standard does not depend on factors such as household-size and occupant behaviors. However, factors in relation to the occupants should be considered carefully in the estimation of city-scale energy conservation because these factors affect energy consumption significantly. Moreover, new residential buildings will be built in cities

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under the 2013 standard and diverse demographics will live in them, and the energy saving effects by the technologies evaluated in the 2013 standard, such as heat pump water heater and cogeneration system, will vary according to household demographics and occupant behaviors.

The purpose of this paper is to evaluate the quantitative energy conservation effects in Osaka Prefecture under the Japanese 2013 standard by using the city-scale residential energy end-use simulation model developed by the authors [2][3]. First, the combinations of technologies that achieve the standard are examined. Then, city-scale energy saving potential of the standard in Osaka Prefecture is estimated by this model. The change of the electricity load curve by implementing the standard is also discussed.

Examination of achievement of the 2013 standard

The 2013 Japanese energy saving standard for newly built residential buildings is composed of a building insulation standard and a primary energy consumption standard. Clients can check whether their planned building adapt to the standard by using the Support Program available on the web [4]. By selecting the specifications on the Support Program, the primary energy consumption of the planned building is calculated, and then whether the building achieves the level of primary energy consumption standard is decided.

In this section, combinations of technologies that adapt to the 2013 standard are examined by using the Support Program. The examination is performed by changing the setup conditions, such as heating, cooling, hot water, and power generation. The setup conditions are shown in Table 1. For the building insulation level, "Base" means the same insulation level as the 2013 standard and "Countermeasure" (High insulation efficiency) means an insulation level exceeding the standard.

Table 1. Setup conditions in examination

	Base	Countermeasure
Building condition	Building site: Osaka Prefecture (Zone 6*1 / A4*2)	
	Total floor area: 120.07 m^2 (a living and dining room, a kitchen, a bathroom, 4 bedrooms)*3	
High insulation efficiency	Average overall heat transfer coefficient of envelope (U_A)*4	
	0.86 $W/m^2/K$	0.39 $W/m^2/K$
	Solar heat gain coefficient in cooling duration (η_{AS})*5	
	2.8%	1.8%
High-efficiency air conditioner	Heating and cooling facility: Air conditioner (Usual specification)	Heating and cooling facility: Air conditioner (Most efficient specification)
Photovoltaic power generation system	No adoption	Generation capacity: 3 kW (South)
Condensing gas water heater	Gas water heater	Efficiency: 95%
Gas engine cogeneration		"Type 2" (Latest specification)
PEFC cogeneration (Polymer Electrolyte Fuel Cell)		"Type 6" (Latest specification)
SOFC cogeneration (Solid Oxiside Fuel Cell)		"Type 2" (Latest specification)
Heat pump water heater		APF (Annual Performance Factor): 3.5
Solar water heater		Thermal collector area: 3 m^2 (South)

*1 The zone classification based on HDD divides Japan into 8 zones (Zone 1–8). *2 The zone classification based on global solar radiation divides Japan into 6 zones (Zone A1–A6).
*3 Design example of LEHVE (Low Energy Housing with Validated Effectiveness) [5]. *4 2013 standard: U_A = 0.87 $W/m^2/K$ (Zone 6). *5 2013 standard: η_{AS} = 2.8% (Zone 6).

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The qualification for the standard is examined for total 52 cases, which are combinations of the base technologies and the countermeasure technologies shown in Table 1. We assumed that a photovoltaic power generation system and a solar water heater are incompatible because of the restriction of roof area.

The status of achievement of the 2013 standard in each case is shown in Figure 1. The upper table shows the combinations of technologies. The lower bar chart shows the primary energy consumption calculated by the Support Program. The cases whose primary energy consumption is lower than the standard value (solid line in the chart) achieve the 2013 standard. The uppermost row in the table shows case numbers and achievement status. The cases represented with black cells achieve the standards, and the cases with white cells do not achieve the standard. Fifty cases achieve the 2013 standard and only Case 1 (BAU) and Case 3 (high-efficiency air conditioner) do not achieve the standard. These results show that photovoltaic power generation system, SOFC cogeneration, PEFC cogeneration and heat pump water heater are very effective. The effect of a PV is especially remarkable. In the following sections, the five major cases that adapt to the 2013 standard easily will be evaluated.

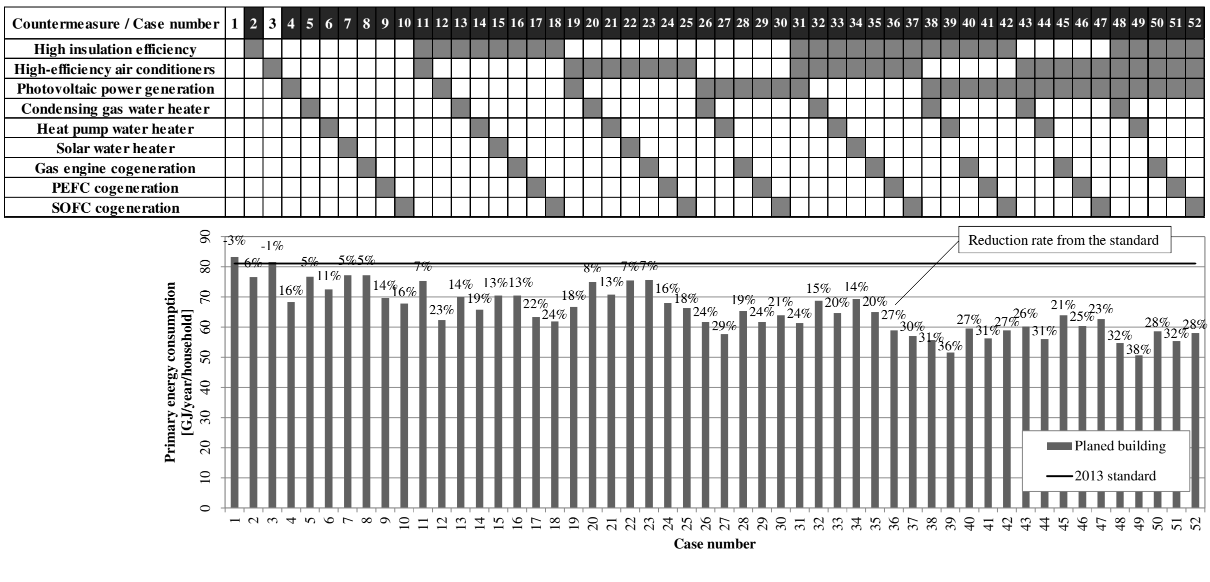

Figure 1. Achievement status of the 2013 standard

Simulation method of residential energy end-use

In the following sections, the energy consumption is estimated by the bottom-up model developed by the authors to simulate city-scale energy consumption in the residential sector [2][3]. This model considers the diversity of family and building types in the city. The energy consumption of one household is calculated iteratively for 19 household categories (e.g., ”Working man”), as well as 12 building categories – six are classified as detached houses and the other six as apartments depending on floor area (e.g., “Detached house 100–120 m^2”). The total residential energy consumption in Osaka Prefecture (population: 8.9 million, households: 3.8 million) is estimated by multiplying the simulated energy consumption by the number of households in each category and then summing the multiplication products.

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Five cases evaluated in simulation

From the result of Figure 1, adoption of photovoltaic power generation system, SOFC cogeneration, PEFC cogeneration or heat pump water heater, without combining with any other technologies, are able to achieve the 2013 standard sufficiently.

High-efficiency air conditioners and condensing gas water heater are not sufficient alone, but are easily able to achieve the standard in combination with each other (Case 20 in Figure 1). Furthermore, these technologies are advantageous because not only can existing equipments be replaced easily but also they are available at relatively low initial cost. Today, the 2013 standard is applied to only newly built residential buildings, but it seems that some policy or standard for existing housing stock will be also necessary. Therefore, the case of the combination of high-efficiency air conditioners and condensing gas water heater is also considered in this simulation.

Table 2 shows the cases evaluated in the simulation. It is assumed that all households in Osaka Prefecture adopt the technology in each case. In addition to the five cases that adapt to the standard, the business as usual (BAU) case is also evaluated. In the case of photovoltaic power generation (PV), it is assumed that PV is installed in only detached houses and all apartment houses are set as same as AC+LHB case since it is difficult to evaluate the adoption of PV in apartment houses in the 2013 standard. About the other technologies, the simulation is evaluated in same setup condition as Table 1 generally.

Table 2. Cases evaluated in the simulation

Case name	BAU	PV	HP	PEFC	SOFC	AC+LHB
Countermeasure	Without any measures	Photovoltaic power generation	Heat pump water heater	PEFC cogeneration	SOFC cogeneration	High-efficiency air conditiones + Condensing gas water heater
Reference with Figure 1	Case 1	Case 4	Case 6	Case 9	Case 10	Case 20

Estimation of energy consumption in Osaka Prefecture

The simulation model used in this study estimates the total residential energy consumption in Osaka Prefecture by considering the diversity of household type and building type. Figure 2 shows the simulated annual primary energy consumption for the 19 household categories in the BAU case and the PV case. The annual primary energy consumption varies with household member: from 28 to 99 GJ/household in BAU case, from 22 to 78 GJ/household in PV case. The difference in energy consumption due to household category is more than three times. The reduction rate from the BAU case also varies widely by household category (16%–33%). The reduction rate is higher in the categories with longer occupation hours in the daytime, such as “Aged man” and “Aged couple”. This is because only self-consumption of PV output is evaluated in the standard and consumption in daytime increase the reduction.

The estimated primary energy consumption in Osaka Prefecture is shown in Figure 3. The percentages shown in the chart show the reduction rate from the BAU case. The annual primary energy consumption of the BAU case results in 187 PJ in Osaka Prefecture. The energy consumption in each case is 162–172 PJ and the reduction rate from the BAU case is

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8%–32%. The reduction rate in the PV case is the highest. This result demonstrates that the energy conservation potential by the 2013 standard is 8%–32% in Osaka Prefecture.

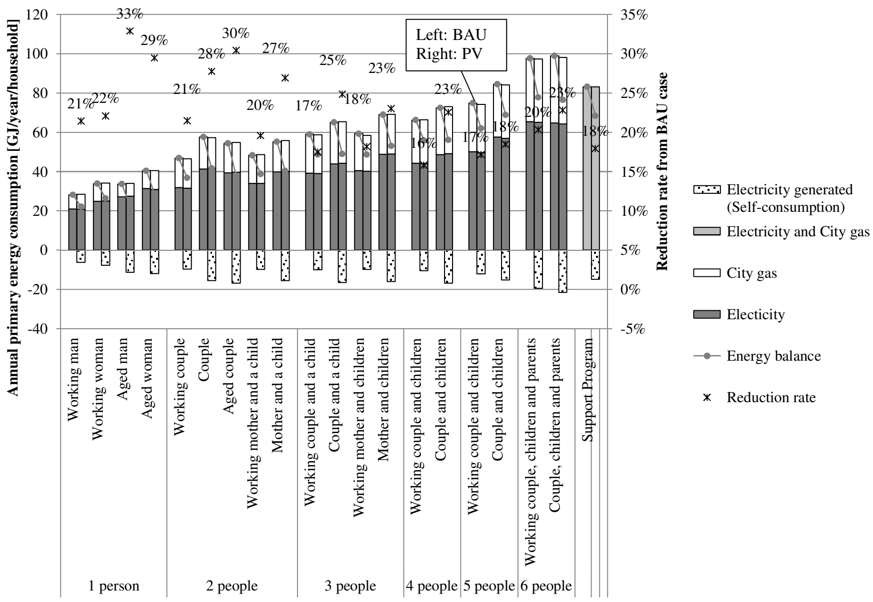

Figure 2. Estimated energy consumption in the BAU and the PV cases (2013 standard insulation level, detached house 100–120 m²)

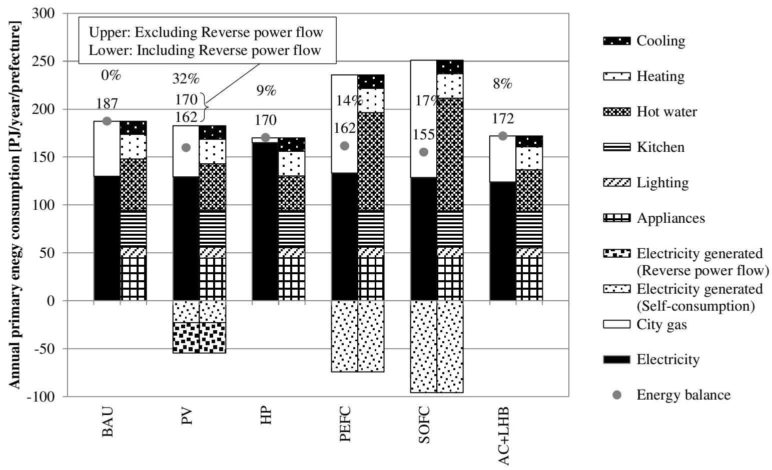

Figure 3. Estimated annual energy consumption in Osaka Prefecture

Table 4 shows a comparison of the reduction rates from the BAU case and the results of the Support Program (Figure 1). Both of them are the reduction rates from the case without any measures. The result of the Support Program and the simulation show a similar tendency, but some differences are also seen. In the PV case, the reduction rate in the evaluation of Osaka Prefecture (excluding reverse power flow) is lower than that of the Support Program because PV systems are adopted only in detached houses. If we evaluate not only self-consumption of PV output but also reverse power flow, the reduction rate in Osaka Prefecture reaches 32%. In the HP case, the reduction rate in the evaluation of Osaka Prefecture is only 9%, whereas it is 13% in the Support Program. In a large household, the energy consumption can be decreased

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greatly by a heat pump water heater; however, in Osaka Prefecture, single households and two-person households account for a substantial percentage of the total households and so the energy reduction rate is limited.

Table 4. Comparison of energy reduction rates between the simulation result and the Support Program

Case name in simulation	BAU	PV		HP	PEFC	SOFC	AC+LHB
Case number in Figure 1	1	4		6	9	10	20
Support Program (one household)	-	Excluding Reverse power flow	18%	13%	16%	18%	10%
Simulation result (Osaka Prefecture)	-	Excluding Reverse power flow	15%	9%	14%	17%	8%
		Including Reverse power flow	32%				

Estimation of electricity load curve

Figure 4 presents the result of the estimated electric load curve of residential sector in Osaka Prefecture for each case. The electricity demand on typical for two days in summer is shown. The most effective case of decreasing the electricity demand is the SOFC case. The late-night electricity demand is 0.1–0.2 GW. This is 9%–15% of the demand at the same time of the BAU case. Thus, the electricity generated by SOFC cogeneration can cover most of the electricity demand.

In the PV case, the demand reduction due to PV generation is very large and the electricity demand in Osaka Prefecture can be negative in weekday daytime. At the same time, the demand varies enormously and the fluctuation range can extend to 3 GW in Osaka Prefecture. It seems that taking some countermeasure to absorb the demand fluctuation will be necessary when PV use is extensive.

The HP case has a characteristic peak load in the early morning. The electricity demand is concentrated from 4 am to 6 am. This is because a heat pump water heater operates to complete boiling hot water in a storage tank in the hours with the lowest tariff. If all households in Osaka Prefecture adopt heat pump water heaters, the peak demand caused by boiling reaches as much as 4.7 GW, whereas in the BAU case the peak load is 3.3 GW. It seems that a distribution of boiling time is necessary if heat pump water heaters are commonly adopted.

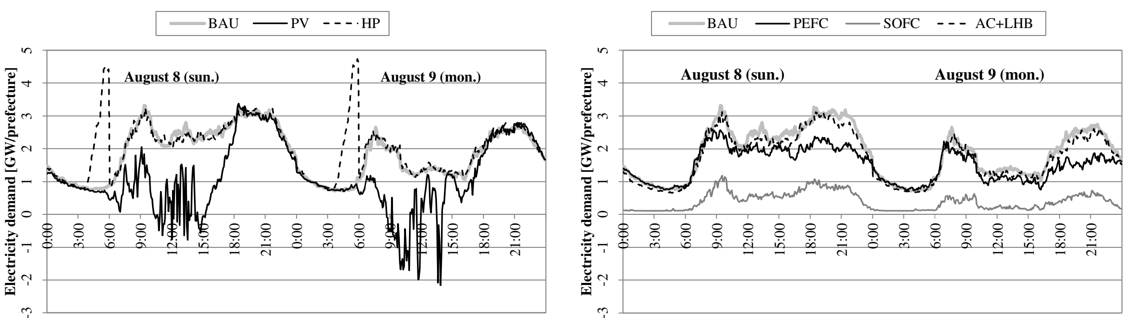

Figure 4. Estimated electricity load curves in Osaka Prefecture

In the PEFC case, the electricity demand is reduced in nighttime. This is because the electricity generated by PEFC cogeneration becomes large while the electricity demand and the hot water demand are high. In the AC+LHB case, the reduction is smaller than that in other cases, but the electricity demand is decreased during holidays and on weekday nights.

Conclusion

From the examination of combinations of technologies for achievement of the 2013 standard, the standard is achieved sufficiently by stand-alone adoption of photovoltaic power generation system, SOFC cogeneration, PEFC cogeneration or heat pump water heater. The simulation clarified that the annual energy conservation potential in Osaka Prefecture is 8%–32% of the total energy consumption in the residential sector. The estimated load curves demonstrated that widespread implementation of PV increase the demand fluctuation and that of heat pump water heaters greatly increase peak load in early morning. It suggests that some countermeasures against such a load curve change should be implemented.

In this paper, an evaluation was performed by assuming that all households of Osaka Prefecture adopt the technologies. However, the technologies will spread gradually due to the replacement of housing and equipment stock under the standard. In future work, the authors intend to estimate the number of houses adapting to the 2013 standard by considering the replacement of stock in order to predict the transition of the energy consumption in residential sector.

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Value propositions for business models for nZEB renovation

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Abstract: *It is poorly understood what the characteristics are of households who want to engage in nZEB single-family home renovations. This paper addresses the research question: What are customer segments, and what are their customer values and motives to choose for a nZEB renovation of privately-owned single-family dwellings in the Netherlands? Research methods are a literature review, a home-owners questionnaire and home-owners interviews.*

In the Netherlands customer segmentation for nZEB renovations currently is not useful because of the limited actual size of the market. One could focus on somewhat older households, high educated and with an income which is on average or above. Characteristics of the dwelling, the energy use, the technical status and inherent comfort levels could be taken as main ingredients for value propositions. Trust in professional involved actors and objective advise are very important issues in customer relationships.

Keywords, nZEB renovation, single-family homes, value propositions, business modelling, energy efficiency

Introduction

The existing housing stock in Europe is predominantly of poor energy performance and consequently in need of renovation work. Nearly zero-energy building (nZEB) has been introduced by the recast of the Energy Performance of Buildings Directive [1], which has set a very general framework and asked the Member States to elaborate their national approaches and implementation plans.

Renovations are often constrained by financial and market barriers. Generally it is assumed that lower costs, lower burden for the client, limiting renovation time and guaranteed energy performance are preconditions for a volume uptake of nearly zero-energy renovation in the privately owned housing sector in Europe [2]. To remain competitive with future new-build houses, house renovations need to go beyond implementing single energy saving measures and should be integrated major renovations or deep retrofitting [3].

However, it is poorly understood what the characteristics are of households who want to engage in nZEB single-family home renovations. What is significant about owner-occupied homes is that those initiating the retrofitting and those living in the house before, during and after the retrofitting are the same people [4]. According to Gram-Hanssen, in most cases, these people do not have specific technical knowledge or an interest in retrofitting. In other words: What are their motives to choose for a nZEB-renovation of their house? Also, it is not

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well understood who they are, how they can be reached and what type of relationship with actors that have the specific technical knowledge, they value [4].

This paper is based upon the first results of an ongoing Intelligent Energy Europe project, entitled "COHERENO - Collaboration for housing nearly zero-energy renovation" [5]. The main objective of this project is to strengthen the collaboration of enterprises in innovative business schemes for realizing nZEB renovations of owner occupied single-family homes. The research is performed in five countries: Austria, Belgium, Germany, the Netherlands and Norway, in order to identify regional business modelling issues - particularly customer segmentation and value propositions for suppliers - that can lead to improved collaboration of actors and to identify the need for quality assurance in these countries, in order to increase customer confidence of such home renovations. The paper addresses the following research question: What are customer segments, and what are their customer values and motives to choose for a nZEB renovation of privately-owned single-family dwellings in the Netherlands?

Research methodology

The business model of Osterwalder and Pigneur [6] is used as a reference for the COHERENO project. The right side of this model about value propositions and customer segments is used as the reference for this paper and to set up a home-owners questionnaire. The model defines customer segments as different groups of people or organizations an enterprise aims to reach and serve. Value propositions are the bundle of products and services that create value for a specific customer segment. Channels are the means how a company communicates with and reaches its customer segments to deliver a value proposition and customer relationships are types of relationships a company establishes with specific customer segments [6].

National studies on the willingness to invest in energy renovation of private home-owners provided insights to define customer segments and value propositions. Furthermore an on-line home-owners questionnaire and three interviews with home-owners, early adopters of nZEB renovations, but not respondents to the questionnaire, gave additional information about value propositions, customer channels and customer relationships for nZEB single-family home renovation. In the development of the questionnaire particular attention went to finding arguments to increase customer confidence by quality assurance.

Willingness to invest in energy renovation by Dutch customer segments

Not renovation but piecemeal adoption of measures is the norm in the private housing sector [7]. As for energy saving measures in owner-occupied housing, not an intrinsic motivation to contribute to environmental quality, but financial arguments are dominant [8,9]. Improvement of comfort is also an important incentive. In a survey by Westeneng and Van Elst [10] 97% of the households mentioned comfort as an important reason for adopting energy saving measures, followed by cost savings (92%). Environment or sustainability is also mentioned as an important reason, but less frequently (67%). Veltman and van Welzen [8] found different (much lower) percentages, but in the same order of preference.

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Lack of finance, the disorder caused by the works and uncertainty about the energy savings are frequently mentioned in literature as barriers for investing in energy saving measures. Westeneng et al. [11] found from interviews with households that subjects related to freedom of choice and certainty were frequently mentioned. This 'certainty' had much to do with the confidence of customers in the contractor. Home-owners can be uncertain about making a choice between contractors, because they have too little knowledge about their qualities and, related to this, do not know how to select those [11].This is confirmed by Veltman and Van Welzen 8], who stated that 40% of the owners-occupiers were confronted with contradicting information and that 48% found difficulties in distinguishing reliable form unreliable information.

Murphy [7] found a significant correlation between holding an energy performance certificate and adopting energy saving measures; nevertheless, households purchasing a home with an energy performance certificate did not adopt more energy saving measures that those who purchased their home in the same period without such a certificate. Together with the issue of a certificate, the receiver is advised about several (voluntary) measures that are seen as appropriate in his/her situation according to the assessor. However, 60-70% of the recommendations of the assessors are ignored [7]. Murphy [7] identified the following characteristics of households contributing positively to adopting energy saving measures:

- living in a detached dwelling;
- living in an older dwelling (mainly built before 1971);
- aged between 40 and 65;
- having already adopted some energy saving measures.

The last point is confirmed by Westeneng and Van Elst [10], who found that 82% of the households that have adopted energy saving measures are prepared to take new energy saving measures.

Not surprisingly, the immediate period after the purchase of a home is relatively often chosen for adopting energy saving measures [11]; shortly after this period, households are less willing to invest than on average.

Customer segments

The apparently small demand for energy renovations, let alone nZEB renovations, makes a segmentation of the market less relevant and also more difficult to substantiate. Moreover, Westeneng et al. [11] state that individual home-owners are very diverse in their preferences. This obstructs the development of a clear and concise categorisation of consumers; any typology would be not of use because of the heterogeneity within each of the types. Nevertheless, Veltman and Van Welzen [8] have developed, from a survey among home-owners, a classification of three groups, based on commitment to environmental issues. These groups are as follows in Table 1.

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Table 1 Customer segments committed to environmental issues

Segment name	Sample share	Description	Population characteristics
Indifferent	31 %	Uninterested in environmental issues, but do not necessarily have a negative attitude towards sustainability	Mostly younger home-owners, living in relatively affordable housing (mostly flats), low education, modal income
Positive	45 %	Take a position between the “indifferent” and the “fans” as for attitude towards sustainability	Mostly middle-aged, living in a terraced house
Fans	24 %	Positive attitude towards sustainability	On average somewhat older home-owners, high education, high income, living in larger and more expensive homes

Source: Veltman and Van Welzen [8].

According to Veltman and van Welzen [8], each of these groups needs a different communication strategy for the adoption of energy saving measures. More information about this can be found in Burghouts et al. [12]. They presented the respondents several ‘propositions’, which did not only include measures, but also means to get these measures realised, for instance by offering a finance scheme or someone who would take care of all the arrangements. Education level, income and age were important factors for not only the willingness to invest in energy saving measures, but also for the choice of the propositions.

Initiated by the Dutch Ministry of the Interior and Kingdom Relations the organization Platform31 carries out the policy programme “Energy Leap” (NL: EnergieSprong) for the built environment. One of the projects called “The Accelaration for the private sector” ((NL: Stroomversnelling) is targeting the refurbishment of owner-occupied single-family dwellings according to the ‘Energy bill = 0 principle’. Consortia of builders, architects, product suppliers and other professional actors are challenged to make renovation proposals for ‘Energy bill = 0 houses’, to be realised in ten working days and an investment of maximum 45.000 Euro (including VAT).

By means of a questionnaire owner-occupants of single-family row houses built between 1950 and 1980 and a monthly energy bill of 175 Euro were asked for their interest in having their house refurbished to an ‘Energy bill = 0 house’, for the price of their current energy bill, based upon a mortgage of 30 years [13]. One third of the respondents are (very) sure that they will accept this offer, one fourth of the respondents will likely accept the offer and one third has doubts. 16% will decline the offer. The researchers conclude that the innovators and early adaptors are especially high educated couples, between 35 and 40 years old and with a higher income. Often they live less than 10 years in the current house and they appreciate a new look for it. Asking for drivers and barriers, the most mentioned drivers are value increase of the house, energy savings, a limited renovation process, no energy bill and more comfort. Barriers are the high investment, an extra mortgage and overall for the respondents the lack of clarity and certainty of the offer.

Findings of the home-owners questionnaire and interviews
In previous work of the COHERENO project a so-called nZEB radar was used to define a pool of home-owners that renovated their house [14]. These home-owners were addressed with the demand-side questionnaire.

The households of the Dutch respondents (17) exist for 44% about one or two persons and 66% of three persons and more. None of the households is below 40 years old. 77% is between 40 and 60 years old, meaning that also older households are interested in energy renovations. Their annual income level is above average. The majority of the households financed the renovation with their own savings.

The motives for initiating the renovation were especially to reduce the consumption of energy (indicated by all respondents) and to improve indoor comfort or health conditions. Various physical needs such as needed repairs of building parts and building services were just for a minority important to decide to renovate. To reduce draught from windows and doors, and a more comfortable indoor temperature in winter were the most important indoor comfort and health conditions. Looking to financial reasons saving on the energy bill was an important reason to renovate. Also of some importance were a reasonable payback of the investment and an increase of the property value. Looking to environmental reasons it is clear that the respondents found important a low or minimum energy use, to produce their own energy, to reduce the impact on the environment and to have a healthy indoor environment. One of the interviewees said: “Important motivations for the renovation were using energy as less as possible and to live comfortable. Moisture problems were prominent in the house, effecting the health and comfort. In any way, we had to do anything about those problems”. Another interviewee: “I presume the payback time of the insulation investments less than 10 years. If not, than the market value and the comfort has been increased”.

Respondents to the questionnaire noticed as their biggest challenges in the renovation project and reaching high energy efficiency:

- to evaluate alternative energy-efficiency solutions;
- to make sure that all (new) building systems work proper together;
- to align insulation measures with airtightness of the house;
- and to get guarantees about the energy savings and the renewable energy generation.

Respondents and interviewees point to the fact that offten just the standard solutions are in mind of in the nZEB renovation professional involved parties. Interviewees stress the point to experience (new) unknown solutions before a final choice, e.g. a pellet stove. An interviewee said: “Home-owners are not able to choose the right measures, even proposed by professional firms, because the firms are in the first place driven by figures. That different contractors bundled themselves in coalitions gave the needed trust in their approach and their offers”. Another interviewee: “The process till the final offers gave trust in the contractors. They were highly motivated. An extensive energy advise gave trust in reaching the desired end result.” The third interviewee: “Trust of home-owners is based upon keeping to the made

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appointments. Home-owners need an independent place to share their experiences with energy renovations".

The customer channels that were listed the most by Dutch respondents are internet, web pages and e-mail, and the notice of similar projects. Part of the respondents are actively engaged with energy efficiency, working as an architect, adviser or constructor, or working for a governmental organisation promoting energy efficiency.

Discussion and conclusion

Obviously energy cost savings and comfort outcomes motivate home-owners for energy-efficient renovations. Organ et al. [15] conclude in their UK-study on motivations for energy refurbishment in owner-occupied housing that the principal reasons are energy bill savings, to increase comfort and to reduce the environmental impact. Whether owner-occupants have a more 'egocentric' or 'altruistic' attitude influences the strength of these principal motivations. Also the technical status of the dwelling could be a motive to renovate, however less important. Building components that have to be replaced because of technical reasons, could be replaced by energy-efficient ones. Indeed, this matches with the immediate periode after the purchase of the house to adopt energy saving measures. This also means a potential for the implementation of energy-efficiency measures within mainstream building work to existing buildings. Wilson et al. [16] propose six conditions which are relevant to the emergence of renovation decisions: conditions ranging from balancing competing commitments to the physicality of living. In respect of energy-efficient renovations they propose to bundle or package energy efficiency measures into amenity renovations. For business modelling this means that appropriate customer channels are e.g. kitchen contractors and not insulation contractors. This approach shows similarities with initiatives in the Netherlands to open local energy savings renovation stores, in some cases as a shop-in-shop, emphasizing energy measures as a normal product to buy for your house next to other products like sun screens and carpets.

As stated before, house renovations need to go beyond implementing single energy saving measures. Taking energy measures within the mainstream building work makes a deep nZEB retrofitting of homes insure. Home-owners tend to start to make their house energy efficient without having the desired end result in mind. That may cause disinvestments. A clear end result and an outlined phased approach is needed, because not all home-owners are willing and able to invest in deep retrofitting as a one-of integrated concept.

In the Netherlands customer segmentation for nZEB renovations currently is not useful because of the limited actual size of the market. One could focus on somewhat older households, high educated and with an income which is on average or above. Characteristics of the dwelling, the energy use, the technical status and inherent comfort levels could be taken as main ingredients for value propositions.

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Trust in professional involved actors is a very important issue in customer relationships. Trust based upon objective advise, a solid piece of work, intrinsic motivation of professionals in energy savings and the willingness to combine knowledge and experience with other actors. In case of nZEB renovations architects can play an advising role and can communicate with home-owners, as a an actor trusted by the home-owners. Clear commitment of the professionals towards energy saving, e.g. expressed in energy saving guarantees, is important.

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Contractor Perceptions of Very Energy Efficient New Multi-storey Residential Buildings

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Abstract: *To facilitate design of policies and strategies which aim to promote a sustainable development of the built environment, a deeper understanding of factors influencing the decisions taken in construction projects is needed. This study investigates Swedish contractors' perceptions of the new-build of very energy efficiency multi-storey residential buildings (e.g. passive houses). The results of interviews with twenty selected contracts managers disclose several perceived disadvantages and risks associated with such buildings which influence the interest to invest in high energy efficiency. These include several cost and market-related issues as well as issues relating to the performance of the buildings. Without market intervention it seems unlikely that very energy efficient multi-storey residential buildings will diffuse to any substantial degree within the Swedish construction industry.*

Contractors, energy efficiency, perceptions, barriers, drivers

Introduction

The newbuild of very energy efficient buildings such as passive houses instead of less energy efficient buildings constitutes an important part of achieving goals of reduced energy use and climate impact of the built environment. Depending on the heat supply, designing a multi-storey residential building to passive house standard instead of to current Swedish building code (BBR 2012) can reduce lifecycle primary energy use by 20-30 % [1]. However, less than 5 % of new-builds in Sweden meet passive house standard, among which most projects are aggregated in a few regions [2]. Compared to other European countries such as Austria and Germany, in which passive houses are increasingly common [3], many areas of Sweden thus have yet to see such buildings and the majority of buildings are designed to poorer energy efficiency.

Compared to conventional buildings, the construction of very energy efficient buildings typically involve thicker insulation, minimizing of thermal bridges, higher air tightness, and installation of a mechanical ventilation systems with very efficient heat recovery [4]. In addition to energy and greenhouse gas related benefits [1], such investments may provide good business opportunities for building developers [5]. Still, the diffusion of very energy efficient buildings seems to face several hindrances relating to, e.g., strong focus on investment costs [3], low expected costs for heating and electricity [6], limited knowledge about and demand for very energy efficient building amongst actors of both on the supply and demand side of residential buildings [3, 7], and perceived problems with the indoor environment [3, 5]. Whether or not such perceptions are consistent with an objective reality, they reflect experiences of reality and therefor guide behaviour [8] such as the decision on whether or not to build to very high energy efficiency.

Alongside construction clients, contractors are perceived as one of the most influential actors in the development of the Swedish construction industry [9, 10]. This follows from that clients often appoint main contractors large influence over the decisions taken in construction projects [11]; contractors often have an intermediary position between construction clients and suppliers [12] and may be allowed to substitute specified solutions with functionally equivalent more cost-efficient ones [11]; and that larger Swedish contractor organisations increasingly engage in property development themselves [13]. Larger contractor organisations thus play dual roles in the development of the Swedish construction industry as the main executive and often most influential actor in construction projects with an independent construction client, and/or as property developer, in which case the construction client belong to the same organisation as the contractor. However, little is known about how Swedish contractors in general perceive newbuild of very energy efficient multi-storey residential buildings (henceforth "multi-storey passive houses") and what their perceptions imply for the diffusion of such buildings. The few known studies [4, 5] only investigates the perceptions of a selected few contractors with passive house experience. This paper aims to further the understanding of contractors' perceptions by presenting the results of interviews with twenty contracts managers at Swedish contractor firms. The purpose of these was not to gather perceptions of representative samples of those with or without experience from passive house projects, nor to get a statistically valid result, but to get an overall picture of the perceptions of the trade. The results can be used to outline drivers and barriers to a more energy efficient built environment, and facilitate the design of policies and strategies to promote it.

Method

Twenty interviews were conducted with contracts managers at Swedish contractor firms in four Swedish municipalities. In each municipality interviews were conducted with one contracts manager at three of the largest Swedish contractor firms and one contracts manager at two smaller (middle-sized) contractor firms. All firms were capable, and had a history, of building multi-story residential buildings. The semi-structured interviews lasted for about an hour and explored the contract managers' perceptions of the pros and cons involved with very energy efficient multi-story residential buildings and the future development. Because the interviewees differed in personalities, priorities, experiences, and interpretations, the outcome, e.g. the amount of time spent on particular questions, differed somewhat between interviews.

Theory

Rogers [14] defines an innovation as an idea, concept, process or system that is perceived as new to potential adopters. Very energy efficient multi-storey residential buildings such as passive houses can be understood as innovations for Swedish contractors in general since they are perceived as new by early adopters [4] and have yet to break into the mainstream market [2].

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In addition to prior conditions and the characteristics of the decision-making unit, the perceived characteristics of an innovation are important antecedents to the decision on whether to adopt the innovation or not [14]. Important elements in the evaluation of the innovation include the relative advantages or disadvantages associated with it, the perceived complexity of adopting the innovation, and the compatibility with existing values, experiences and needs. The relevance and outcome of these evaluations can be expected vary between individuals and organisations, and between different adopter categories. For instance, while early adopters of an innovation may be more venturesome and require less reassurance of the benefits involved, later ones might not adopt unless they perceive the innovations as properly evaluated or are forced to adopt by contextual factors [14, 15]. To be able to effectively design policies and strategies which aim to promote the innovation, e.g., multi-storey passive houses, it is important to understand the common perceptions of the important decision-making units, across adopter categories.

Results

The interviews disclosed several factors which, according to the interviewees, influence the will and/or capacity to invest in energy efficiency in new multi-story residential buildings. The following review is an account of such perceptions.

Additional Costs

All interviewees perceived passive houses as more, or significantly more, expensive than conventional multi-storey residential buildings. Combined with a perceived lack of interest from construction clients and occupants, this was by most interviewees perceived as the primary barrier to increased energy efficiency. The costs associated with energy efficiency were discussed from several different perspectives.

According to the interviewees, energy efficiency involves additional construction costs following from the greater use of materials (e.g. thicker insulation), the use of more expensive materials, the more expensive installations (in particular ventilation systems), and the greater amount of work hours which follow from the materials and tasks (e.g. building a thicker wall). The higher requirements on air tightness in very energy efficient buildings and the more careful and aware construction workers it necessitates, so to avoid punctuations in the building envelope, were perceived as the primary difference between conventional and very energy efficient construction processes. High energy efficiency was also perceived to require more thorough planning and projection in the initial stages of the construction project.

Four interviewees had experience from multi-story passive house projects. Three of these estimated the additional construction costs involved to about 5%. Another three interviewees did a similar estimation, while yet another three estimated the additional construction costs to 10-15%. Remaining interviewees thought it impossible to estimate the difference. These interviewees meant that the construction costs depend on many different factors which are difficult to survey, and they had never been in the situation where they had to calculate the costs of two identical options with different levels of energy efficiency. In addition, they

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meant, if the projects aims for high energy efficiency it should be reflected already in the early design, and such ambitions often involve other choices, e.g., use of recyclables, which also influence costs. For certified buildings such as passive houses there may also be additional costs involved due to the administration of certification schemes. These were, however, perceived as proportionally smaller in multi-storey buildings than in detached ones.

Several interviewees also mentioned other factors which influence costs and directly or indirectly could influence the capacity and/or will to invest in energy efficiency. Among these, the building shape and design (including local or municipal demands on shapes and facades), the ground conditions, and regulations and norms regarding accessibility and the sound proofing of apartments were most often mentioned. There was also mentioning of norms for parking lots per apartment and that, in rentals, the budget is dependent on the regulated allowable maximum rent per square meter. Some interviewees perceived banks as influential through the credits and loan they give to construction clients and apartment buyers. Energy companies could, according to interviewees, influence through their pricing of heating and electricity, e.g. if there is a fixed price regardless of use, and depending on whether or not they see business opportunity in installing e.g. district heating in energy efficient buildings. In general, energy prices were perceived to be too low to motivate the additional costs involved with high energy efficiency.

The budget for apartment buildings was perceived as extremely tight, in which it was perceived to be difficult to make ends meet already and there is a constant quest to reduce costs. Lifecycle costs calculations were perceived to be rare and clients to focus primarily on initial investment costs. It was the perception of several interviewees that it is equally or more important to reduce costs than energy use. Even if there would be stronger market demand for energy efficiency, the interviewees meant, the equation is difficult to solve. The perception of the interviewees was that few can afford to build and/or live in a multi-storey passive house. Some had built very energy efficient detached houses and believed it to be easier to cover the costs involved with these than with a multi-storey house. Although the higher energy efficiency may reduce administration and heating costs, the large investment costs was argued to not allow landlords and property developers to reduce the rent to the extent that it is attractive to tenants or buyer-occupants. The fact that the thicker walls of very energy efficient buildings mean less saleable or rentable floor area was also raised as an issue.

Market and Demand

The only advantage mentioned with multi-storey passive houses was the reduced energy use. All interviewees found the quest towards reduced energy use and environmental impact important and unavoidable. Accordingly, the will to invest in multi-storey passive houses was perceived as primarily driven by construction clients' and contractors' will to market themselves as environmentally friendly and visionary businesses. This was, in turn, perceived to be influenced by the public opinion and perceived energy efficiency interests of potential clients and/or buyer-occupants.

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Construction clients were perceived as pivotal for the energy efficiency of multi-story residential buildings but relatively uninterested in very high energy efficiency and unwilling to take the additional investment cost involved. Among clients, municipal housing companies were perceived to have higher demands on energy efficiency than private ones, while larger private client organisations were perceived to have higher energy efficiency demands than smaller ones. The explanation for this, meant the interviewees, might be that larger organisations more often build to administer while smaller clients more often have short-term goals in mind (e.g. to sell the building to a tenant-owner cooperative). Most interviewees engaged in property development, of which all but two built to stronger energy efficiency demands than the national building code requires. The rationale for this was related to the business profile.

The public demand for very energy efficient buildings was by most interviewees perceived as the most important drivers towards increased energy efficiency. However, although younger generations were perceived as more interested, the public was at present not perceived to give much importance to energy efficiency in housing decisions. Several interviewees felt that the development has come further in office and commercial buildings, where clients and customers have marketing incentives to reduce their energy use and environmental impacts. In residential buildings, however, occupants were perceived as uninterested and unwilling to pay. Because of the costs and lack of demand, multi-storey residential buildings were perceived to come in last when it comes to adopting anything new.

Risks and Uncertainties

In addition to cost aspects, the interviewees perceived several uncertainties regarding the performance of very energy efficient dwellings. These mostly related to the indoor environment and the efficiency of ventilation systems in air tight buildings. There were also uncertainties related to the perceived newness of the concept and that it has not been around long enough to be properly evaluated. Several were concerned about the lifetimes of the plastic in the building envelop and what may happen if it crumbles or the ventilation does not work as intended. The interviewees expressed concerns over whether occupants or landlords would run and administer the building so that the ventilation works as intended and moisture problems are avoided. The fact that apartment occupiers were perceived as uninterested in energy efficiency was perceived as a risk to the proper maintenance of the building.

To convince buyers and tenants, all actors involved in the construction sector, e.g. from energy companies to real estate agents, were argued to need more knowledge and be convinced about the benefits involved with multi-storey passive houses, which was not perceived as the case at present. Instead, several interviewees expressed concerns over that tenants and buyer-occupants might expect problems with the thermal comfort and indoor environment of very energy efficient buildings. Lack of coherent standards for what a very energy efficient building is, and an abundance of certification schemes, was also argued to make it difficult for consumers to understand their choices.

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Because multi-story passive houses were perceived as untested technology, several interviewees meant that the uncertainties necessitate a slow, step-wise and reflective development. Another reason for this, meant some interviewees, is the possible future technical development. Considering the development of the past, meant these interviewees, it would be irrational to invest en masse in current technology, as more cost, time and space-efficient solutions may be waiting around the corner. Some also argued that, due to the costs and uncertainties associated with a very energy efficient building envelope, one had perhaps better to focus on improving installations, e.g. install individual meters for heating and hot water and systems for hot water recovery instead.

Energy Policy and Regulations

Although construction clients were perceived as most important, local (municipal) governments were perceived as the strongest driver towards increased energy efficiency in residential buildings. In addition to their role as clients, several of the municipalities chosen for interviews had local political directives meant to stimulate energy efficiency, e.g. discounts or favouring in allotments for very energy efficient projects. This was generally not perceived as problematic, but as a significant driver towards change within the industry. Some interviewees, however, perceived it as a barrier to industrialised building.

The national building codes on energy efficiency were perceived to be weak and most interviewees found it easy to build to significantly higher efficiency (often about 25 % better, e.g. 75 kWh/sq. m) than the codes currently prescribe. This was by several interviewees perceived as a good level that is “energy efficient enough”, whilst higher efficiency was perceived to require a lot more effort, costs and uncertainties. Most interviewees predicted higher demands on energy efficiency in the future. However, several had the perception that if very high energy efficiency would be required, there would be no activity in the construction sector.

Conclusion

Swedish contractors perceive several disadvantages with very energy efficient multi-storey residential buildings. These include lack of demand from buyers, tenants and construction clients and several cost-related aspects and uncertainties to the performance of the concept. These aspects seem to be given greater importance than the environmental benefits of very high energy efficiency, and do not favour adoption and diffusion of such concepts. Significant energy efficiency improvements seem to be perceived as long-term goals which allow for a slow and step-wise development, rather than something that requires prompt action. Such an approach is also favoured by perceived uncertainties in energy price and technological developments.

In general, Swedish contractors seem to perceive multi-storey passive houses as expensive profiling projects which primarily are built for marketing purposes and have yet to be evaluated properly. Without market interventions or other changes to the context in which contractors and construction clients decide to invest in very high energy efficiency or not, it

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seems unlikely that wider diffusion of very energy efficient multi-storey residential buildings will occur to substantial degree within the Swedish construction industry.

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Thermal stress and comfort in elderly people's housing in tropical climates: the need for policy

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Abstract: *The challenges of heat-related mortality and morbidity call for research on the need for policy in tropical countries. This paper discusses gaps between current international policies concerning thermal-related issues in health and housing for the elderly. An extensive literature review addresses problem definition, determination of the policy implications and examination of appropriate responses. Investigation of heat-related mortality demonstrates greater impact in tropical compared with temperate climates. Temperate countries experienced a 0.6-1.0% increase over background death rates due to excessive heat, whereas increases of 1.8-5.7% and 1.3-13.0% were found in subtropical and tropical countries respectively. Thermal stress and comfort policies have been implemented in some developed countries, but little attention has been paid to the thermal comfort of elderly people in the tropics. This paper suggests that holistic management, both before and after heat wave events, should be provided to avoid the condition of low-grade misery among the elderly.*

Keywords, Thermal stress, thermal comfort, elderly, policy

Introduction

Aims. This paper discusses gaps between building design guidelines and current international policies concerning thermal comfort in the elderly. It also identifies gaps between heat-related reporting and the effect of heat on health. The aim is to help inform the development of appropriate heat-related policies which address both short-term responses (e.g. heat wave warning systems) and longer term urban design considerations.

Method. The main focus of this paper is on tropical developing countries and thus on extreme heat rather than cold. An extensive literature review comprised three steps: problem identification; determining the scale of policy implications for both thermal comfort and thermal stress; and simultaneous examination of the policy responses in developed countries. The thermal-related policies in the temperate developed countries of Japan, Australia and the US are discussed as examples.

Problem definition and scale. Thermal comfort depends on both physical factors (ambient temperature, wind speed, radiant temperature and humidity) and psychological factors (activity, expectation and acclimatization). The elderly, defined here as adults aged 65 years or more, are at particular risk from thermal stress, due to deterioration of physiological thermoregulation associated with aging [1, 2]. Degradation of the neurosensory systems in the elderly can lead to delayed responses and less awareness when they are exposed to critical high and low temperatures [3]. Globally, heat-related deaths are likely to rise as a result of an increasing proportion of adults 65 + in the total population. In 2013 the ratio was 12% but it is projected to reach 21% in 2050, with 32% in developed countries and 19% in developing countries [4].

Temperate climate cities experience a lower incidence of heat-related mortality than cities in tropical countries. Table 1 shows that heat-related deaths among the 65+ age group are estimated to rise from 0.6% of total deaths in 2002 to 15% in 2030, in Central Asia [5]. It is predicted that a temperature rise of 5°C from the threshold temperature of 27°C in Tokyo will lead to a 1.02% growth of heat-related deaths across the entire population [5]. In the summer of 2013, Tokyo experienced a maximum of 37°C which led to 9,815 additional out-patients experiencing heat-related illnesses and 17 additional deaths [6].

Australian temperate cities are predicted to experience even higher death rates from extreme heat events than tropical cities by 2050 [17]. Heat stress victims of all age groups in Adelaide, Melbourne, Perth, Sydney, Hobart and Brisbane totaled 1,115 persons in 2003 and the number is estimated to increase to 2,300-2,500 in 2020 and 4,300-6,300 by 2050 (Table 1) [7, 17].

Subtropical Hong Kong evidences the same trend. An increase of only 1°C above the summer mean temperature of 28.2°C led to an increase in the total death rate of 1.8% [9]. The summer data indicated a two-fold increase in heat-related deaths of 65-year old plus at over 26 °C of net effective temperature (NET)[1] [10]. The morbidity rate in Hong Kong also convincingly demonstrated a link between higher temperatures and cardiovascular and respiratory infections. The influence of the urban heat island (UHI) in Hong Kong in summer of 3.67°C [11] appeared to cause an increase in the death rate of 4.1% in the urban core with average winds and 5.7% in calm conditions. For the incidence of heat-related illnesses, non-cancer diseases showed a rise of 5.2% within the urban core and a 4.7% increase outside the UHI area. However, Taiwan (Table 1) experienced lower death rates than highly urbanized Hong Kong, with 22 additional elderly dying when temperatures exceeded 30°C [12]

Research on heat-related problems affecting the elderly in tropical countries such as in Southeast Asia is very limited. In the Thai data, summarized in Table 1 and in non-heatwave conditions, [13] the 5-13% of deaths attributable to heat in 1999-2008 is estimated to increase by 8% by 2100 with a projected increase of 4°C from a threshold temperature of 31°C [14]. Chiang Mai is projected to experience a 1.29% increase in heat-related deaths in the same circumstances. The morbidity rate for diabetic and circulatory out-patient visits and admissions is projected to increase by 19-26%, increasing by 5% with every 1°C temperature rise [15a].

Table 1 National heat-related mortality and morbidity summarized

Country	Data year	Max T_{mean} (°C)	Threshold T. (°C)	Mortality	Morbidity	Projected		Reference
						T. (°C)	Mortality	

[1] Net effective temperature (NET) is one of the thermal perception indices. It includes relative humidity and wind factors in the assumptions.

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Country	Data year	Max T_{mean} (°C)	Threshold T. (°C)	Mortality	Morbidity	Projected T. (°C)	Projected Mortality	Reference
Temperate climatic zone								
Asia, Central	2002	-	> 35°	0.6%*	-	+4° (2030)	+ 0.7-15% in 2030*	[5]
Japan, Tokyo	1972-2008	-	+5 from 27° threshold	+1.02%*	-	-	-	[5]
	2013	37°	-	17 people	9,815 out-patients	-	-	[6]
Australia	1997-1999	-	> 28°	1,115 people	-	+0.5 - 2.35°	2,300-2,500 (in 2020); 4,300-6,300 (in 2050)	[7, 8]
Subtropical climatic zone								
Hong Kong	1998-2006	31.8 °	> 28.2°	+ 1.8 %	Cardiovascular disease and respiratory infection	-	-	[9]
	1971-2000	-	> 26°	Doubling of heat related deaths*	Heat stroke	-	-	[10]
	2001-2009	28.3° Urban, 23.9° Rural	> 29°	+4.1% (urban heat island & average wind); +5.7% (UHI & calm)	Non-cancer : urban area +5.2% , rural area +4.7%	-	-	[11]
Taiwan	2007	34°	>30°	22 people*	-	-	-	[12]
Tropical climatic zone								
Thailand	1999-2008	40°***	> 31°	+5-13%	-	+4°	+8% in 2100	[13]
Thailand, Chiang Mai	1999-2008	33.5°	> 31.7°	+1.29 %*	Cardiopulmonary	-	-	[14]
	2002-2006	28°	29°	-	Diabetic, +19-26% ; circulatory, +5% per +1°C	Max. = 38° by2050 [15b]	-	[15a]
	1995-1997	30.4°	5.35° above 31°C ****	+2.39 %	-	-	-	[16]
Thailand, Bangkok	1991-1992	32.3°	8.09° above 31°C ****	+5.78 %	Cardiovascular	-	-	[16]

*Note: "Max T_{mean}" denotes the mean maximum temperature in daytime, in summer; "Threshold T" denotes the temperature which can start to impact subjects. *The data in the table refer to the elderly population. **Assume 0% adaptation. ***Summer peak temperature. ****The threshold temperature for heat-related effects in this research was 31°C.*

The examples above denote that heat-related mortality is likely to become a more serious problem over the next few decades due to the impact of global warming. It raises the critical question of whether and how governments are responding to rising death rates through policy initiatives.

Results of policy responses. Notwithstanding the existence of thermal comfort based building design guidelines, few official responses are evident in developing countries in the tropics. The summary of actions by different countries (Table 2) shows that indirect thermal stress initiatives have been implemented only in some developed countries. These have achieved beneficial outcomes both in terms of lives and financial savings. For instance, Japan [18] has established an online warning system for the entire population with hourly monitoring when temperatures exceed 35°C [19], similar to Hong Kong [31]. A heat-health warning campaign established in Philadelphia, USA saved the lives of an estimated 117 elderly people with researchers suggesting significant but indirect economic savings to society. These early warnings covered the period from 1995 to 1998 and cost only USD $210,000 [20].

Table 2 Elderly health or housing policies and their heat-related issues

Country	Year	Policy or Initiative	Key Actions	Heat-related Issue
Japan	2008-now	Early Warning Information on Extreme Weather [18]	- Displays online the early warning information on extreme weather for every hour over 35°C	TS
	2013-now	*Health and Welfare Bureau for the Elderly* and *Long-term Care Insurance Act 2012* [19]	- Creates 'Long Term Care Insurance system' - Increases long-term care service centres	X
Australia	2002	Ageing in Place [21]	- Designed principles for ageing in place by combining with the Building Code of Australia	X
	2003	*Improving care for older people: A summary of Policy for Health Services* [22]	- Promotes 12 principles of health services and health independence	X
	2006	*Improving the environment for older people in Health Services: An Audit Tool* [23]	- Created a four-part audit program: General environmental audits support rehabilitation	TC
	2007	Accreditation Standards 4.4 Living Environment [24]	- Standard 4.4: Physical environment and safe systems - Comfortable internal temperatures and ventilation	TC
	2009	Special Climate Statement 17 [25]	- Designed 'Severe weather warnings'	X
	2011	*Council of Australian Governments Long Stay Older Patients (COAG LSOP) Victorian* [26]	- Provides strategies, plans and approaches to improve appropriate health care services for older people	X
	2012-now	Liveable Housing Design Guidelines [27]	- Provides standards for housing performance and accreditation - Focuses on physical safety and comfort	X
	2012-now	*COTA Australia Policy and Position Statements* [28]	- Includes climate change impacts and the thermal efficiency of older people's homes	TS/TC
	2013-now	*BASIX thermal comfort protocol* [29]	- Includes thermal comfort criteria for all residential dwelling types	TC
USA	1995-1998	*Heat-health warning campaign* in Philadelphia [20]	- Implemented warning campaigns; cost $210,000 and saved 117 lives in a 3-year term	TS
	2010-now	ASHRAE standard 55-2010 [30]	- Includes guidelines on indoor air temperatures for thermal comfort	TC
Hong Kong	2001	*Single Elderly* or *Elderly Persons Priority Scheme*	- Encouraged elderly persons to reside together	X
	2001	*Senior Citizens Residence Scheme*	- Contributed housing assistance for the elderly	X
	2011-2012	*Ageing-in-Place in the Policy Address of 2011/12*	- Guidelines for the physical, social and cultural environment - Supported health-care staff and 'active ageing'	X
	2014	*Weather Information for Senior Citizens* [31]	- Designed 'Severe weather warnings' for the elderly	TS
Taiwan	2014	Severe Weather Advisories [32]	- These services display basic multiple weather conditions but are not oriented specifically to thermal stress or thermal comfort	X
Thailand	2014	Warning News [33]		X

Notes; "X" denotes lack of evidence of heat-related policy; "TS" denotes the presence of thermal stress-related policy action; and "TC" denotes the presence of thermal comfort-related policy actions. Documents in normal text are formal enacted policies. Documents in italics are guidelines.

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On the other hand, despite extreme heat in Australia, Hong Kong, Taiwan and Thailand [25, 32, 33], integration of health and housing policies has still not been achieved, as shown in Table 2 [21, 22, 26, 27]. Four initiatives in Australia can claim to have addressed thermal aspects in housing for the elderly. For example, '*Improving the environment for older people in Heath Services: An Audit tool'* was implemented in 2006, and incorporates thermal issues in the audit checklist [23]. Also, Australia's Council on the Ageing (COTA) addressed thermal efficiency in housing for the elderly to support better health as well as energy efficiency outcomes [28]. COTA [28] released the first Australian guideline for a satisfactory thermal environment for older people's homes. More generally, a thermal comfort protocol has been implemented for all residential types in the State of New South Wales, including seniors' housing, under the Building Sustainability Index (BASIX) program. [29]. The American ASHRAE standards, widely applied globally, [30] suggest that residential air temperature in summer should be between 23-26°C although this does not account for occupant age or existing thermal control systems. Finally, Hong Kong's weather warning system provides information on two websites, one of which displays weather data in an aged-friendly version [31].

Some design guidelines address thermal control, but most are directed at air-conditioned buildings. Southeast Asia countries have in general responded inadequately to the need for guidance on thermal performance while Thailand as a developing country has to date, not provided any guidance on these matters.

Discussion

Although policies to date have tended to focus on weather warnings and physical housing design for the elderly, a reasonably comprehensive literature review suggests that the integration of both remains surprisingly neglected. Poor people in tropical developing countries are likely to suffer more in extreme temperatures than people in temperate climates, due to the unaffordability of air-conditioning. Tropical countries clearly need to develop thermal-related polices, aspects of which are discussed below.

First, elderly people in situations of poverty are more likely to be impacted, and impacted more severely by adaptive limitations. Studies in both developed and developing countries have confirmed that the most vulnerable people with regard to heat exposure are likely to be older persons, in particular poor people who cannot afford cooling appliances or good quality housing [34-38]. Secondly, an increase in warmer weather will result in more health costs in the coming decades. Australian researchers found that a 4°C temperature increase would result in a fivefold rise in heat-related health costs (from AUD$61 million to $393m) but would also result in a fourfold decrease in cold-related costs [36]. Finally, thermal stress can play a significant role in mortality not only in older people, but also in those with conditions such as cardiovascular disease irrespective of age. For instance, after the heat wave in Japan in 2003, the female adult heat-related death rate was higher in every age group, not just the elderly [39].

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Future integrated initiatives to address the issue of thermal stress could incorporate actions both before and after a heat-wave event. Pre-event actions should not only include warning campaigns directly aimed at elderly people and caregivers such as those applied in Hong Kong [31], but also focus attention on housing design guidelines for the elderly. Huang (2013) recommended that extreme heat risks should be managed through early warning, healthcare preparedness and awareness and education. After a heat-wave event, the relevant agencies can evaluate responses to inform continual improvement.

Thermal comfort initiatives tend to be more subjective given there are significant psychological factors involved. However, a key concern about the elderly is their well-being both physically and psychologically. Physical issues can be addressed by improving the physical environment, such as by providing better thermal monitors and control systems, better thermal design for housing, and urban design to mitigate the urban heat island. Psychological issues are strongly linked to occupant satisfaction. One of the thermal comfort policies from Hong Kong [40] suggested that housing policies should target dwelling temperature, lighting and air quality through better design. Although older persons might not associate personal discomfort with thermal conditions or complain about them, this does not necessarily mean that they feel comfortable. They may be suffering from low-grade misery.

Conclusion

The literature indicates convincingly that excessive heat is dangerous to health and leads to increased mortality and morbidity across temperate, subtropical and tropical climates. Thermal stress policies have been launched in some developed countries such as Japan, Australia and the US, but very little attention has been paid to the thermal comfort of elderly people in the tropics. Additional research is necessary to assess the long-term effects of their thermal comfort in the context of future global warming and the influence of the urban heat island. There is, for example, still a significant lack of holistic management, in both pre-event and post-event circumstances such as warning campaigns, housing design improvements, and post-event data collection to support planning and design initiatives. Even where no deaths eventuate from thermal discomfort, a more informed policy approach is needed to avoid a condition of low-grade misery among the elderly.

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Session 141:

Where should energy renovation reach up to? (V)

Chairperson:

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EPBD (Energy Performance of Buildings Directive): Evolution or Revolution?

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Abstract: *The aim of this paper is to provide an overview of the challenges that the construction industry faces to meet the objectives of the EPBD directive of the European Union, namely when designing nearly-zero energy buildings. In this perspective, a case study of a Buildng project in France is presented, highlithing the design approach adopted, the performance targets defined, the main challenges to overcome by the market and construction industry, and the solutions possibly adopted. The presentation will look into a project that was delivered 1 year ago with the highest levels of certification (HQE, BREEAM and LEED) and the French label for "low energy consumption buildings" (50% less energy consumption compared to regulation) noticing the impacts of achieving the objective of being a Nearly Zero Energy Building. In addition, a case study of a real NetZEB, with all building energy uses taken into account, will be also presented to exemplify a practical implementation of the concepts highlighted in this abstract.*

EPBD, NZEB, netZEB

Introduction:
In Europe, the Energy Performance of Buildings Directive II established that, by 2020, *all new buildings shall be "nearly zero- energy buildings*" (nZEB), which means that buildings shall be able to produce the great amount of the energy they need during in-use stage, but shall also be designed to drastically reduce their energy demandby integrating highly efficient equipment and envelope. To achieve this ambitious target of almost generalizing passive buildings, the European Member States '*shall draw up national plans for increasing the number of nZEBs*'.

Supported by real case studies, this presentation aims at debating the real challenges of designing (nearly) Zero Energy buildings, by highlighting how this new performance ambition will actually revolutionize the way buildings are designed and operated. Instead of leading to a simple evolution of the design practices, this new European legislation will rather generate a real transformation of considerations and approaches between the stakeholders involved in the development of a project, so that the estimated performance can really be achieved in occupation stage.

The concepts and build examples of nearly zero energy buildings or CO2 neutral already exist in several countries. However, the visions on how these buildings should be defined and the ways to achieve specific national objectives vary across Europe. The definition of NZEB (Nearly Zero Energy Buildings and Net Zero Energy Building) in the recast EPBD offers

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[1] Deerns, Barcelona
[2] Deerns, Group
[3] Deerns, Paris, France
[4] Deerns, Barcelona
[5] Deerns, Paris, France

flexibility, but at the same time leaves doubts about the current level of ambition, CO2 emissions of such buildings, and the consumption aspects to be included in the calculation when designing a building.

Currently, the European Commission, the EU Member States, stakeholders and experts are analyzing the different aspects of nZEBs. In general, there is an urgent need to establish common principles and methods to be considered by the Member States of the EU for effective, practical and thoughtful preparation of NZEB definitions. In practice, Engineering firms are already needing to anticipate these challenges and calculation parameters in order to design today the buildings that will comply tomorrow with the NZEB definitions, knowing that these definitions of low energy buildings have common elements but also significant differences between EU Member States. This presentation will highlight the main differences of approaches, the common field to them and the questions that shall be raised to the market today and in the future.

Nearly Zero Energy Buildings:

The recast of the Directive 2010/31/UE of 19/05/2010 on the Energy Performance of Buildings, establishes the objective of achieving nearly zero-energy for the built environment (Article 9). According to the related directive, a Nearly Zero Energy Building is "A building that has a very high energy performance". The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy produced on-site or nearby.

In compliance with this requirement, policy also states that Member States shall draw up national plans for increasing the number of nearly zero-energy buildings. These national plans may include targets differentiated according to the type of building, to consider their use specificities.

The same Diretive, in its Article 9 - §6, states that: "Member States may decide not to apply those requirements in specific and justifiable cases if the cost-benefit analysis over the economic lifecycle of the building is negative, setting the possibility to define ambitious but necessariliy feasible targets.

Changing the design approach:

The current practice in the design of green buildings is based on: 1) reducing energy demand by suitable design of the envelope (be lean); 2) incorporating high-efficiency systems (be clean); and finally 3) incorporating renewable energy production on-site, if appropriate in the building (be green). [See Figure 1].

If the purpose of a building is being a Nearly Zero Energy Bulding, then the focus of design should be such as to ensure that the building does not consume more energy than the renewable energy available or produceable on site (see Figure 2).

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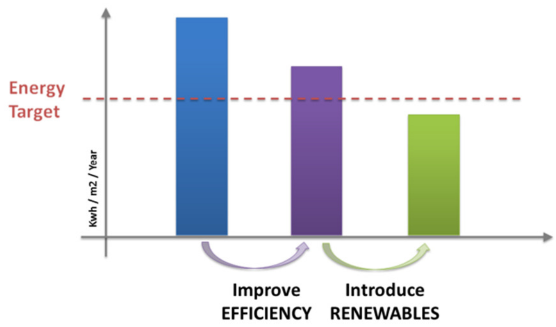

Figure 1. Current green design approach

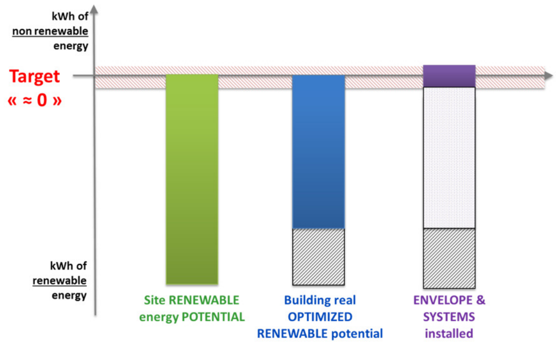

Figure 2. Future NZEB design approach

The first consequence of this new approach is the change of roles and responsibilities of Mechanical and/or Sustainability engineers. Focusing to the NZEB target will require they assist property developpers to identify the best sites suitable for on-site renewable production; define the project's buildable area and size according to the use; and assist the architect in the development of a building able to sort out the program with the available allowable energy.

A project to example a practical concept application:
In order to support the different perspectives and stakes that are considered when designing a nearly zero energy building, a building case study of an 19.000 m2 office building in France (NEWSIDE, La Garenne Colombes), is presented. The mentioned building was delivered one year ago with the highest levels of the main building certification schemes (HQE, BREEAM and LEED). Also, due to its high energy performance features, the building was awarded the French BBC label for "low energy buildings".

Figure 3. « Newside » - Office - France

The different solutions adopted in this building will be presented, demonstating the reason why it was awarded the PREBAT prize by ADEME (French Environment and Energy Agency) recognizing the buildings that integrate approaches to prepare the future built environment. New solutions were integrated to optimize the global performance of the buildings, while reducing operating costs and increasing the users' comfort and behaviour awareness. Amongst the solutions adopted and the technical strategies integrated to deliver this NZEB, we can mention the following characteristics:

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- Strategies for achievement of triple certification: HQE (Exceptional), LEED () andPlatinum) BREEAM ();Excellent)
- Optimized performance of the thermal and solar façade;
- The energy-efficient production with thermoelectric heat pumps;
- Indoor climate control, using a radiant ceiling system;
- Detailed measurement and verification of building performance during use stage
- An "hybrid" ventilation strategy (natural ventilation jointly with opening of windows and users' recommended behavior instructions;).

As a result of this innovative and award-winning design, compliant with different programs and rating schemes for sustainable buildings, the NEWSIDE building consumes 51% less energy than a conventional French building. What if we inteded to design Newside to be a Zero Energy Building?

WeAs explained above, this building represents the current Best Practice in terms of energy performance design but what would needhave been required to cover aachieve the NZEB target?

The building's total final energy consumption is 78,6kWh/m²/ year, representing a total of 1.493.300kWh / year (19,000m² x 78,6kWh/year). To offset this energy consumption and get to the NZEB level, 5800m² of photovoltaic panels would be required, which in theory would represent an additional cost for the client of 4 M€ (215€/m²). When we analyse the situation, the building site had 6000m² with a total construction cost of €. 2000€/m²…possible solutions

Impacts on the Building Industry, to meet the targets:

For the Property market:

Considering the requirement of the directive, it is necessary to analyze the considerable implications it may have on the property market.

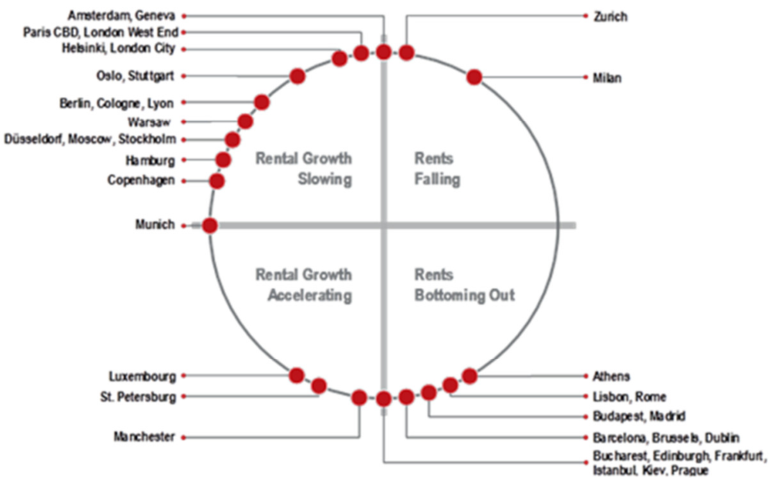

Figure 4. European property market situation. Source: JLL

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As show in Figure 4, Europe has currently mainly a saturated office property market. This situation is provoquing both construction costs and rents to be driven down. In the current situation, can the market still absorb the potential NZEB overcosts?

Or, if Refurbishment regulation is less stringent, would the Market be heading for Renovation rather than New Construction, with its high potential costs due to regulation evolution and faster obsolescence risks?

The Energy Usage in buildings:

The Energy Performance of a Building is: "The calculated or measured amount of energy needed to meet the energy demand associated with a typical use of the building, which includes, inter alia, energy used for heating, cooling, ventilation, hot water and lighting"; according to the Directive.

Taking as an example the case study presented before, Figure 5 shows the anticipated energy consumption calculated with different tools and taking into account all the energy consumption of the building. While the energy calculated with advanced simulation tools may actually be twice the energy consumption calculated with regulatory models and its consumption elements, the figure shows how the real energy consumption taking into account the unregulated energy uses may indeed be four times the one initially estimated one (calculated with the regulation official software).

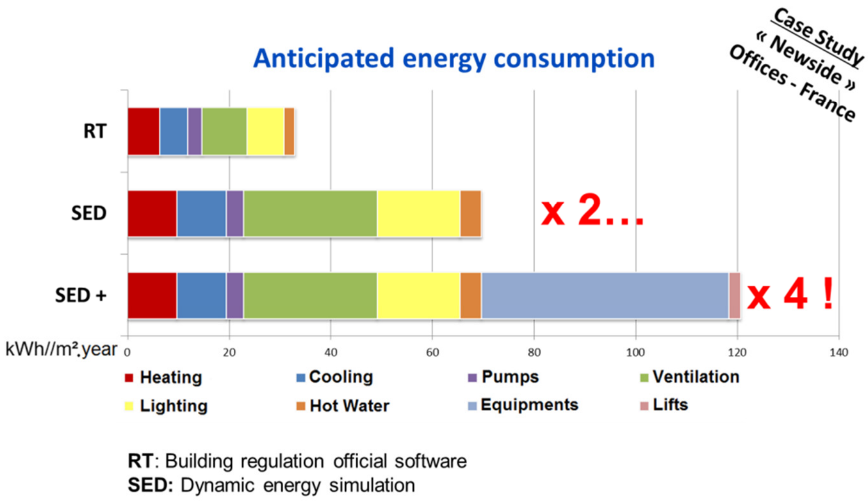

Figure 5. Anticipated Energy Consumption. « Newside » - Office - France

From the point of view of confort and technology included in buildings, new passive approaches may arise: could it be considered that future office building would have, for instance, no more cooling equipments (representing today 20% of an office energy); or, must new technics with passive systems be included, such as electrocromatic glass or concrete activation?

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Other environmental criteria:

Some changes may also be necessary on the existing Environmental Rating Schemes, namely on some criteria aiming at generating environmental benefits. Actually, some doubts may appear on the way buildings will be able meet some of the requirements of the Directive, together with some of measures included in these worldwide recognized systems.For example, if roofs are completely covered with photovoltaic panels, then there would be no space for roof vegetation and local biodiversity preservation on buildings located in an urban environment; In this configuration, it may also be difficult to introduce measures for rainwater management; or it can also affect to the heat island effect provoqued by the building in the surroundings.

Emergence of new responsibilities for the Mechanical / Sustainability Engineer

In this new regulatory and building targets framework, it will necessarily appear new approaches to management and project design in order to achieve the aimed global performance. Some of the new services that a design team or the sustainability engineer may have to provide are the following:

- Property market trends anticipation & Identification of the best sites
- Define the project's buildable area and size
- Assessment of Architect's choices on the passive design for minimizing energy demand
- Innovation / use of new products and solutions
- Energy Performance Guaranty
- Avoid designing over-complex systems, so that the maintenance and operation of the building run efficiently.
- Anticipate the building's lifetime (for maintenance and Facility Management costs estimation)

Maison de l'Ile de France, a true NetZEB

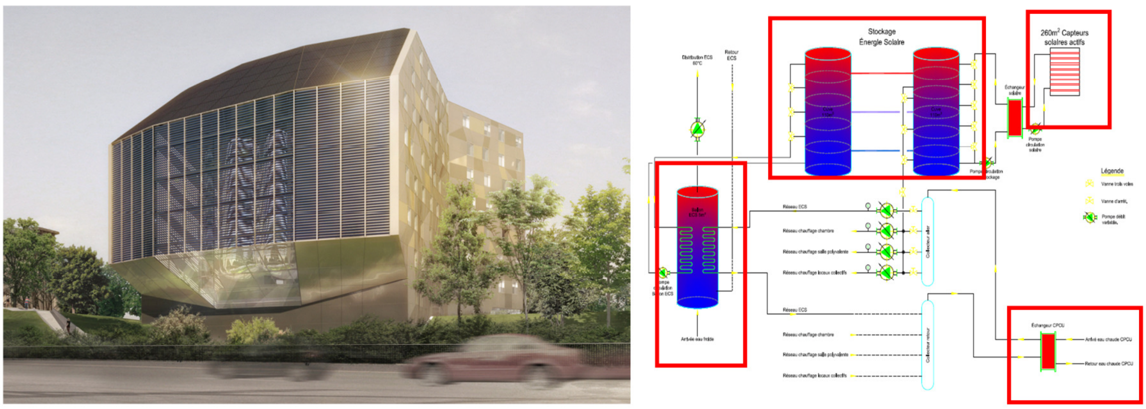

Figure 6. Project's south façade and solar thermal strategy

This student residence project in Paris designed by Deerns is aiming to achieve the NetZEB target and beyond the EPDB requirement (including non regulted energy).

The approach explained above was implemented on this project: 100% of heating, domestic

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hot water (DHW) and electricty will be provided by the sun.

- The heating and DWH styrategy is based around two 100m3 tanks that will store the heat produced from evacuated tude solar thermal panels located on the building's south façade. The heat accumulated during the summer and autumn will be used in the winter season. In the summer, the excess heat will exceptionally be sold back to the district heating network operated on site.
- The most efficient photovoltaic panels (21%) available on the market on be located horizontally on the roof.
- Based on detailed calculation using dynamic thermal simulation, the building envelope was designed based on the available energy produced by the systems above.

Discussion and Conclusions:

It2014, it is our opinion that the implementation of the EPBD in future national building regulations in Europe will represent a major challenge to building industry as a whole, starting already today. The main conclusions and recommendations of our presentation, based on a real case study, are the following:

- **Challenges for Engineering when dealing with the building's whole lifecyle:** technical difficulties and opportunities of the zero-energy buildings.
- **Transformation of design team's practices & processes**: team interaction (primary site selection) and the evolution to transversal approaches; will the architect tend not to pilot the whole process and may the MEP/Sustainability engineer assume leading responsibility in the Building Performance management (as it happens with Data-Centers) during the building lifetime. Would users be heavily involved in defining expected building usage?
- **Variation of design scenarios for energy consumption**: Regulatory energy consumption or total building consumption? What to consider in the nZEB calculation and will it include process loads? What design strategies may be applicable in different countries (solar power in Italy or ATES in Netherlands)?
- **Integration of new technologies and solutions:** which new technologies breakthroughs may change the way we design buildings? Increase in PV panels efficiency, phase change materials, electro-chromatic glass…)
- **Adaptation of the Market requirements and impact in the building Rating Tools (LEED, BREEAM, HQE,…):** How will the property market adapt itself to the future requirements of a nZEB? Will air conditioning still be a "must have"? Will the Building Scale still be the only parameter or will it be necessary a change of dimension, where building design will necessarily consider the neighborhood scale, evolving from green buildings to green cities? What other associated effects should be looked at? Will a building covered with PV panels increase the heat island effect, reduce the potential vegetated areas and biodiversity, increase the storm-water runoff…?
- **Green Value**: what construction over-costs and operating savings may arise?
- **Creation of Green financial mechanisms**: For buildings not achieving the required "zero-energy" target, new taxes for property developers may arise, to cover existing building's refurbishment or to fund renewable energy projects.

By addressing the topics above, this presentation aims at showing the challenges and opportunities for the European Market, regarding the implementation of Nearly Zero energy Buildings.

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Illustration of methodological challenges in energy and environmental assessment of buildings

Speakers:
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Abstract: *A life cycle approach (LCA) is now commonly used for the environmental assessment of buildings. However, different methodological rules are currently found in the literature to estimate the energy and LCA balance for the use stage e.g. from an annual assessment to a one hour time step assessment. Another critical issue is related to the assessment of new low energy buildings equipped with on-site renewable energies. In this study, first, the consequences of using different Life Cycle Inventory (LCI) calculations for the electricity mix are analysed. Then, the consequences of using different allocation rules for the on-site renewable energy produced by PV panels are assessed. The results on a single individual house showed that the use phase results are very sensitive to the allocation rules. Regarding the temporal aspects, this study highlights the differences between dynamic and static approaches for both energy and LCA calculations. Finally, recommendations are given to improve the reliability of building LCA tools.*

Keywords: Life cycle assessment, energy efficient building, building environmental assessment, renewable energy, time step

1. Introduction

The building sector is a major contributor to the environmental impacts including climate change, energy consumption, waste generation and air pollution [1]. The environmental stakes are particularly important in construction because any initial decision has always long-term consequences. One of the methods suggested to evaluate such environmental impacts is Life Cycle Assessment (LCA). LCA provides a holistic approach that is based on studying "the whole industrial system involved in the production, use and waste management of a product or service" [2]. Although LCA first emerged from the packaging industry, it has gradually spread into many sectors, including the construction industry and led to the development of several building LCA tools with their own data, methodologies and environmental indicators [3].

Currently, environmental authorities and policy makers use LCA to choose environmental strategies. A critical issue in the building sector concerns the assessment of nearly zero energy building (nZEB) and plus energy building i.e. over the year, they should produce more energy than they consume. Most of these buildings are or will be equipped with on-site renewable energy production e.g. PV panels, solar thermal panels, wind power, geothermal heating to fulfil the current and future regulations. For instance, in France, all new buildings should be

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plus energy buildings in 2020 [4]. On the one hand, solar decentralized renewable energy production units can annually produce more energy than the building energy consumption. On the other hand, they may produce energy while the users of the building do not need it e.g. during the day when the users are out of the building (respectively they may not produce energy while the users need it e.g. during the evening).

This statement questions the way the energy production/consumption and the LCA calculations are conducted e.g. in early design or in more detailed assessment. Indeed, no consensus exists on the way to account for the onsite energy production in LCA. Recently, the EN 15978 standard "Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method" recommends differentiating the energy consumed on site, the energy imported from the grid and the energy exported to the grid, separately from the LCA results. In the same time, the standard does not provide any guidance of the choice of the time step for the assessment and recommends to fully allocate the environmental impacts of the on-site energy equipment to the building [5]. Though harmonizing the LCA rules for the European construction sector, the EN 15978 standard can have some consequences in decision making (e.g. encourage or discourage the use of PV in new buildings) that need to be studied in more details.

In this paper, the goal is to understand 1) the influence of the time step used for the energy and LCA calculations and 2) the influence of the rules for handling the on-site energy production on the impact assessment results of near zero energy building (nZEB) and plus energy building located in France. The next sections present the methodologies tested and the building case study. Results are reported in section 4.

2. Methodology

2.1. Three methods for handling energy and LCA calculation time step

Today, the energy balance (i.e. differentiation between energy consumed on site, exported and imported) for a building is commonly available at the hourly time step e.g. if directly from dynamic thermal simulation results. Common practive consists in using annual energy balance from the thermal regulation. In this study, both annual and hourly energy balance results are used for the following French regulated uses: heating, cooling, domestic hot water, lighting, auxiliaries, ventilation and other uses of energy e.g. appliances (not regulated). Then, for electricity uses, the energy input data are combined with LCA data describing the impacts of electricity consumption.

Previous works have shown the variability of environmental impacts of the French electricity grid mix depending on the day, the week or the month in a year [6]. As all uses of electricity in a building are variable during the year (e.g. for heating or lighting), both hourly and annual LCA data for electricity consumption are considered to assess the sensitivity of the time step from an attributional LCA point of view.

These two types of data for the assessment of energy and LCA are then combined as illustrated in Table 1 and in Figure 1. In this study, case B is assumed to be the most accurate

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assessment while Case C represents common practice (i.e. hourly energy results, aggregated to the year and then LCA calculation with annual electricity mix) and case A may be considered as the simplest option.

Table 1: Energy and LCA data configurations

	Annual energy balance	Hourly energy balance
LCA data based on annual electricity mix	**Case A**	**Case C**
LCA data based on hourly electricity mix	**-**	**Case B**

2.2. Three methods for handling on site energy production in LCA

As stated earlier, the European LCA standard, EN 15978, advices to communicate next to the LCA results, the amount of energy produced on site and allocate the entire energy production system to the building. Nevertheless, for plus energy buildings, it is clear that from a LCA point of view, it is a multifunctional system because buildings become energy producer. Therefore, according to ISO 14044 [7] and ILCD Handbook [8], in attributional LCA (describing the environmental life cycle of the product and not its consequences), two other approaches could be used to deal with this issue: the system expansion, also called avoided burden approach or the co-products allocation. The avoided burden approach considers exported energy as energy not produced by the grid which then results in avoided impacts (proportionally to the average contribution of each energy carrier). All impacts related to the energy system are allocated to the building. Regarding the co-products allocation method, the exported energy is considered as a co-product of the building and the impacts of the on-site production system are affected to the building with a ratio (denoted X in Figure 1) according to the energy consumed on site.

In this study, these three approaches are considered and are illustrated for a building with photovoltaic (PV) panels in Figure 1.

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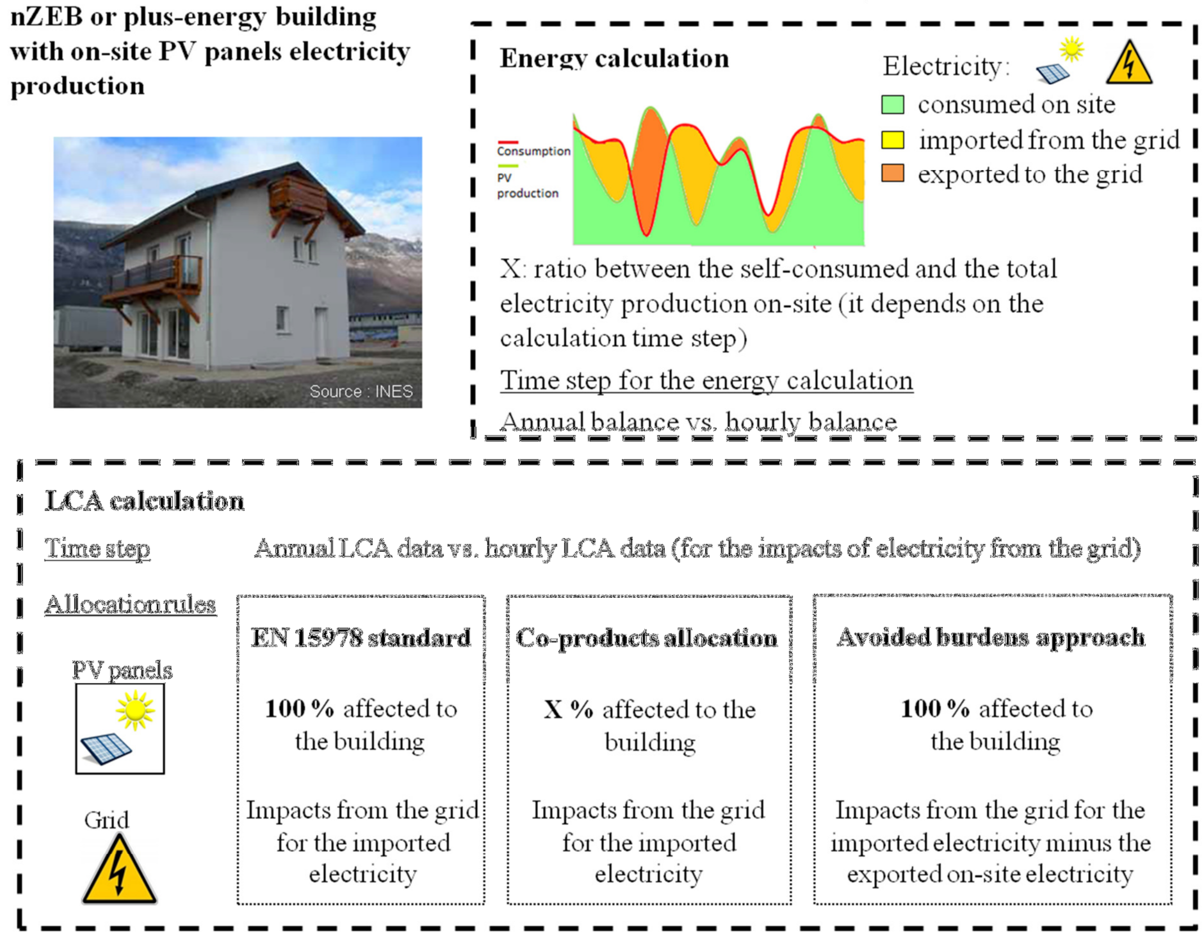

Figure 1: Representation of the methods for handling on site energy production for building equipped with photovoltaic panels.

3. Application to a building LCA case study

In order to test the different methodologies presented in section 2 (cf. Table 1 and Figure 1), a single family house from the INCAS platform, near Chambery, in France, has been chosen as a case study. The INCAS house complies with the passive house standard and has a net floor area of 122 m². Spitz et al. described it in more details [9].

In this study, different alternatives of the house are tested: the INCAS house without PV panels, the house equipped with 40 m^2 of PV panels and the house equipped with PV panels and 4 m² solar thermal panels (used for the hot water needs). The first house is used as a reference case; the second alternative is representative for nZEB and the last one of plus energy buildings.

3.1. System boundaries

The LCA of the buildings include the impacts of three contributors according to the EeBGuide guidance [10]: the building products and equipment from cradle-to-grave i.e. production, transportation to the site, use and replacement, end-of-life (modules A, B, C of EN 15978), the impacts related to the operational energy regulated uses (module B6 of EN 15978 , energy needs at the meter), the operational water uses (module B7 of EN 15978), and

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the specific uses of electricity such as appliances in the building (module B6 of EN 15978). The reference study period for the house is set at 50 years.

3.2. Operational energy use data

The dynamic thermal simulation tool COMFIE was used as well as the 2012 meteorological data of the Bourget-du-Lac (location of the INCAS house). Four inhabitants are considered, consuming each 100 L of cold water and 40 L of hot water per day. The heating demand is covered by an electric air heater and the hot water by an electric storage heater running during the night. In the alternative where solar thermal panels are used, an electric heater is used instantaneously as backup. For the other electrical needs (lighting, ventilation and domestic appliances), the annual consumption is determined using a ratio of 2500 kWh, average consumption per household in France [11]. They are supposed to be hourly distributed along the year according to the house occupancy.

The heating demand is low and equal to 7.5 kWh/m²/year. The overall energy needs of the building are 52 kWh/m²/year in 2012, 40 kWh/m²/year when the house is equipped with solar thermal panels for the hot water and the overall PV production is 41 kWh/m². Figure 2 presents the variability of the total electricity consumption and production for the two alternatives of the INCAS house: nZEB and PEB.

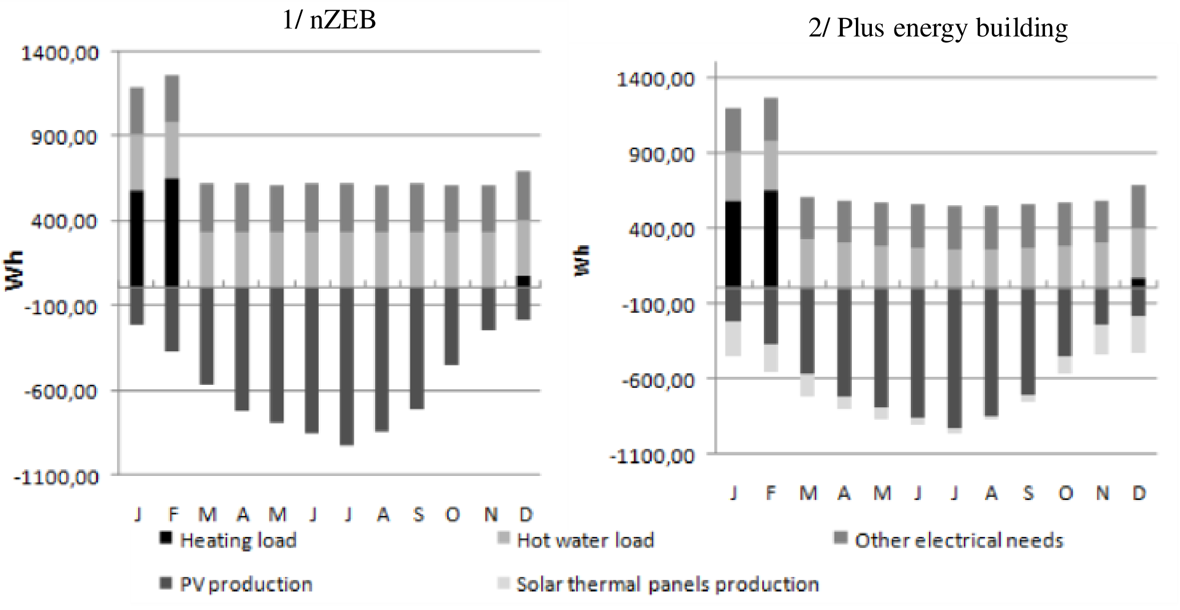

Figure 2: Average monthly final electricity consumption and production in 2012 for the INCAS house with (1) photovoltaic panels and electric heater storage and (2) the house with photovoltaic panels and solar thermal panels (2).

Hourly 2012 production data from the French electricity grid manager (RTE) were used for calculating the hourly and then the annual electricity mix. The energy carriers of the electric mix are break down by technology type: nuclear, gas, coal, fuel thermal plants, hydro-power, wind energy, solar energy and thermal renewable energies (biomass, biogas and industrial waste) as well as electricity import and export with neighbouring countries. For each energy carrier, recent, LCI data from ecoinvent v3 [12] was associated to rebuild an hourly and annual electric mix. The national electricity mix is considered in this study because European environmental objectives (e.g. reduction of energy consumption and CO_2 emissions) are fixed on national bases.

3.3. Building products and technical equipment data

The data describing the LCA impacts of products are taken for all the scenarios from the INIES database [13]. These are Environmental Product Declaration (EPD) from cradle-to-grave [14]. Each EPD has a service life data reported by manufacturers and a scenario for the transport to the building site, its implementation and its end-of-life. For the photovoltaic panels and solar thermal panels, the data used are extracted from ecoinvent v2.2 database [15]:"3 kWp slanted-roof installations, multi-Si, laminated, integrated on roof". Their life time is assumed to be 30 years and the amount is adapted to match the peak power (5 kWp).

3.4. Impact assessment

Seven indicators were used based on the French and European standards for LCA in the construction sector. Table 2 presents the names and units of these indicators.

Table 2: List of environmental indicators considered in this study

Indicators	Units
Non renewable energy	kWh
Water consumption	L
Waste (hazardous and non hazardous)	kg
Radioactive waste	kg
Global Warming potential	kg eq-CO_2
Acidification potential	kg eq-SO_2
Photochemical ozone formation potential	kg eq-C_2H_4

4. Results

4.1. Contribution analysis

Figure 3 shows the LCA results of the reference case (INCAS house without photovoltaic panels) with the annual electricity mix and the electricity consumption of 2012 (Case C). As it is an energy-efficient building located in France, the electricity consumption during the use phase is only a major contributor of two indicators: Non Renewable Energy (83 %) and Radioactive Waste (62 %). It also represents a substantial share of Water consumption and Climate change impacts, respectively 42 % and 39 %.

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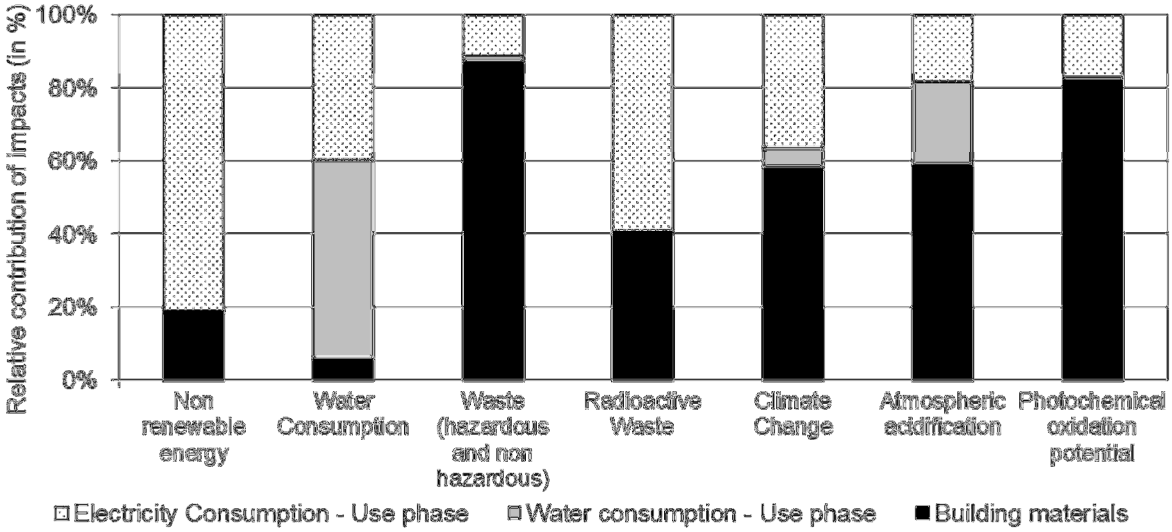

Figure 3: LCA results for the reference INCAS house (without photovoltaic panels) – annual electricity consumption and annual mix 2012 (Case C)

4.2. Import/export energy calculation time step

Table 3 shows huge differences in electricity consumed on-site, imported and exported when the energy balance is done with a yearly or an hourly time step. For instance, the self consumed energy ratio calculated annually is closed to 100 % for both houses whereas it falls to 22 % for the nZEB case and 34 % for the plus energy building case. All methods for handling on site energy production in LCA use these results.

Table 3: Differences between a yearly and an hourly calculation

		nZEB	Plus energy building
Yearly calculation	Electricity consumed on-site (kWh)	5054	4923
	Electricity imported from the grid (kWh)	1241	0
	Electricity exported to the grid (kWh)	0	131
	Self consumed energy ratio	100 %	97%
Hourly calculation	Electricity consumed on-site (kWh)	1121	1708
	Electricity imported from the grid (kWh)	5175	3215
	Electricity exported to the grid (kWh)	3934	3346
	Self consumed energy ratio	22 %	34 %

4.3. Influence of methods for handling on site energy production

Figure 4 presents the results for the cases A, B, C (see Table 1) of the three different methods for handling on-site energy production in LCA for the nZEB and for the plus energy building.

For case A, the three methods for handling on site energy production give the same results whatever the alternative (nZEB or plus energy building). Indeed, the amount of exported

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electricity is small and the self consumed energy ratio is around 100 % (cf. Table 3). These two factors are the ones inducing differences between methods. For the variant comparison, all methods show that the house with PV panels has a better environmental profile than the house without PV panels except for the hazardous and non hazardous waste indicator.

For case B, the differences between methodologies are significant (up to 58 %), especially for the plus energy building. The co-products allocation gives results close to the ones of the house without panels. Similar results are found for the EN 15978 allocation method. Regarding the avoided burdens approach, the results, whatever the building type: nZEB or plus energy, are much smaller especially for the Non renewable energy and Radioactive waste indicators. In fact, the amount of exported electricity is high: more than the half of the imported electricity for the nZEB case and higher than the imported electricity for the plus energy building case (cf. Table 3). Hence, the impacts of electricity consumption are significantly reduced for the avoided burden approach (compared to the reference case) and as seen in Figure 3, the most sensitive indicators to this change are Non renewable energy and Radioactive waste.

For case C, differences between methodologies are smaller than in case B and the results are similar for the nZEB building than those of the reference house (without PV panels). For plus energy building alternative, all methods give smaller results than the reference case. The avoided burden has much smaller impacts than the co-product allocation but only for the non renewable energy indicator. Unlike case B, the radioactive waste results are not very different for the allocation methods. Similarly to case B, the amount of exported electricity is part of the explanation; however, the annual electricity mix does not allow taking into account which energy carrier of electricity is avoided. In case B, mainly nuclear electricity is avoided (depending on the exportation hours) whereas in case C, it is the average energy carrier mix which is avoided i.e. less nuclear electricity is avoided.

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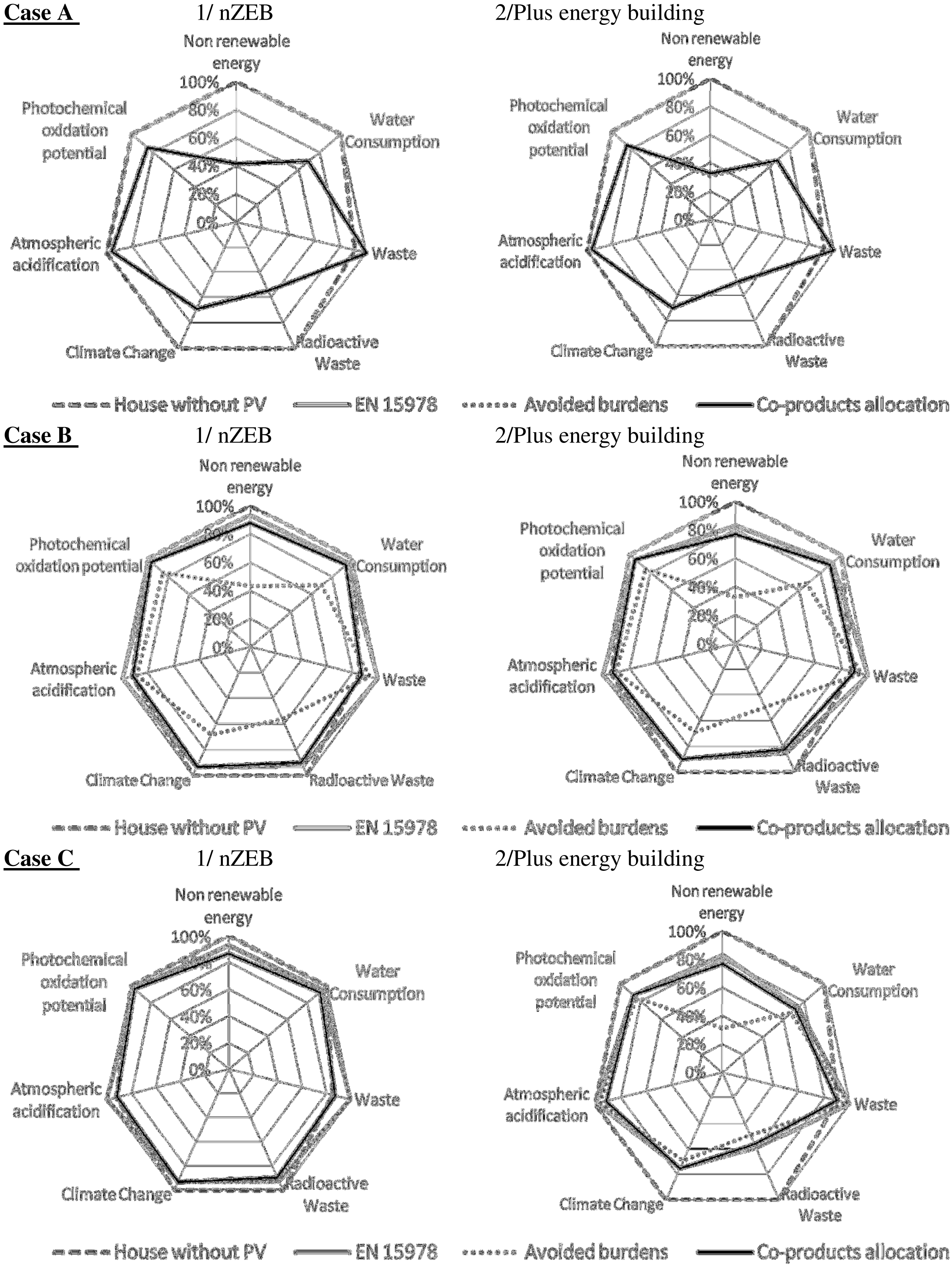

Figure 4: Comparison between the different methodologies for the INCAS house in the configuration nZEB and plus energy building for the annual calculation (A), hourly calculation (B) and hourly energy balance used with annual electricity mix (C). The house without photovoltaic panels is used as reference.

5. Discussion and conclusion

In this study, it was found that differences between methodologies are more important for the plus energy building than the nZEB. Similarly, using an hourly electricity mix led to different results than an annual mix. More differences are also found between the avoided burden and co-product allocation methods when using an hourly electric mix. This is more critical for LCA indicators sensitive to the nuclear and fossil fuel energy carriers' shares of the French grid mix (radioactive waste, climate change).

For these dwellings with photovoltaic panels, it is important to calculate the energy flows at hourly level at least Moreover, choosing an hourly or an annual electricity mix to perform the LCA influences the results; the hourly electricity mix takes into account the variability of production during the year and, will be more accurate physically speaking.

For the different methodologies, between the house with and without panels, the ranking will be the same. However, the numerical results are really different. The avoided burden methods give smaller results for the indicators: typically around 40 % for Non renewable energy, 70 % for Climate change, 55% for Radioactive waste and 70 % for Water Consumption whereas the EN 15978 and the co-products allocation give closer results, typically around 80%.

Furthermore, absolute value for each method depends strongly on how much specific electricity is required yearly by inhabitant: in this study, 20 kWh/m^2 compared to total energy needs of 52 kWh/m^2 and how it is distributed along the time.

Finally, each methodologies, has its own motivation. The EN 15978 gives some advantages to the building exported energy and some advantages for the one that will use this exported energy. The co-products allocation evens out the impacts between the building producing energy and the building consuming the exported energy. The results are more balanced than for the EN15978 method. For the avoided burden approach, the building producing energy is advantaged without implying relations with neighbouring buildings. It considers all environmental benefits and impacts allocated to the producing building, following the idea that the decision maker (the one that have chosen to install the PV panels) is responsible for related impacts and benefits.

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How could Common Carbon Metric be practically usable for international collaboration to reduce greenhouse gas emission from buildings?

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Abstract: Carbon metric is the sum of annual greenhouse gas emissions and removals, expressed as CO2 equivalents, associated with the use stage of the building. ISO/TC59/SC14 is now drafting international standard: Environmental performance of buildings - Carbon metric of a building - Use stage. It aims to set out a globally applicable common method of measuring and reporting of associated GHG emissions attributable to existing buildings, by providing requirements for determining and the reporting of a carbon metric(s) of the building. Carbon metric is just a metric and is not an assessment method for evaluating the overall environmental performance of a building or a building-rating tool, and does not include value-based interpretation. Carbon metric is relevant for snapshot measurement in the operational stage of building. Thus, it is relevant but is different with life cycle assessment (LCA) methodologies. Carbon metric is usable in those countries where experts' services are only limitedly available. Carbon metric provides the basis for global scale carbon trading within building-related sector.

Keywords, carbon metric, carbon intensity, energy use, GHG emission

Introduction

Buildings contribute as much one-third of global greenhouse gas (GHG) emissions (UNEP-SBCI 2009a). With its high share of emissions, the building and construction sector has more potential and opportunity to deliver quick, deep and cost-effective GHG mitigation than any other sectors. In this context, measurement and reporting of GHG emissions from existing buildings is critical for enabling significant and cost-effective GHG mitigation. Currently, there has not been a globally agreed method to measure, report, and verify potential reductions of GHG emissions from existing buildings in a consistent and comparable way. If such a method existed, it could be used as a universal tool for measurement and reporting of GHG emissions, providing the foundation for accurate performance baselines of buildings to be drawn, national targets to be set, and carbon trading to occur on a level playing field.

UNEP-SBCI proposed the idea of Common Carbon Metric (CCM) of a building in 2009 as a protocol for measuring and reporting GHG emissions from the operational phase of buildings (UNEP-SBCI 2009b). Corresponding to the proposal by UBEP-SBCI, ISO/TC59/SC17/W4 has launched to document the international standard on carbon metric of a building (ISO 16745 -Environmental performance of buildings - Carbon metric of a building - Use stage). As a convener and the member of ISO/TC59/SC17/W4, the authors have involved in the process of documentation of the international standard. The process has raised the issues that seem to be significantly influential on the effectiveness of CCM as a sustainability indicator of a building. The paper aims to introduce the content of ISO 16745 and tries to identify the way how CCM could be practically usable for international joint initiative to reduce greenhouse gas (GHG) emission from buildings.

What is Common Carbon Metric (CCM)?
The most recent version of the draft of ISO 16745 at the time of writing of this paper (hereafter ISO 16745) defines carbon metric as “sum of annual greenhouse gas emissions and removals, expressed as CO2 equivalents, associated with the use stage of a building." Thus, carbon metric can be measured by kgCO2e/m2/year. ISO 16745 also defines carbon intensity as “carbon metric expressed in relation to a specific reference unit related to the function of the building.” Here, reference units may include per unit area, per person, per kilobyte, per unit output, per GDP. Thus, carbon intensity could be measured by kgCO2e/m2/year, kgCO2e/occupant/year or etc.

If some organization would successfully construct an internationally agreed method of measurement of carbon metric of building, the method would be able to provide Common Carbon Metric (CCM) of the building. In such case, CCM could facilitate the technology sharing across different climate zones and building types. CCM is needed for consistent, measurable, reportable and verifiable GHG emissions reductions from buildings (UNEP-SBCI 2009b). Such metrics can be applied to measure greenhouse gas emissions in individual buildings or groups of buildings. They are also the basis for monitoring emissions mitigation on regional and global scales (UNEP-SBCI 2009b). ISO 19675 aims to set out a globally applicable common method of measuring and reporting of associated GHG emissions attributable to existing buildings, by providing requirements for determining and the reporting of a carbon metric(s) of the building.

Relevance and difference with assessment tools and LCA
ISO 16745 does not include any method of modelling of the operational energy use of the building. Carbon metric is just a metric and is not an assessment method for evaluating the overall environmental performance of a building or a building-rating tool such as LEED, BREAM and CASBEE. ISO 16745 does not include value-based interpretation of the carbon metric(s) through weightings or benchmarking. In principle, accurate and precise reporting can only be achieved if GHG emissions (and removals) from all life cycle stages of buildings are measured and/or quantified as is defined in life cycle assessment (LCA) methodologies. However, not all countries in the world have sufficient capacity or resources to use and apply LCA as is defined in EN15978. Respecting on the necessity for collaboration in a global scale, there exist a need for a metric that is usable not only in countries where the sufficient number of experts and a precise database are available, but also in those countries where

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experts' services are limited, and precise databases are not available. With the potential for global scale carbon trading within building-related sectors, a method that is consistently usable in both the well-developed and developing world is needed. CCM aims to respond to such needs. Operational energy use in buildings typically accounts for 70-80% of energy use over the building life cycle. Therefore, the operating stage of the building's life-cycle is the focus of measurement and reporting of direct and indirect GHG emissions. This is the reason why ISO 16745 focuses on operational stage of building

System boundary of carbon metric of building

ISO 16745 defines the three types of carbon metrics of a building as follows:

- Carbon metric 1 (CM1) is the sum of annual GHG emissions from building-related energy use;
- Carbon metric 2 (CM2) is the sum of annual GHG emissions from building- and user-related energy use;
- Carbon metric 3 (CM3) is the sum of annual GHG emissions and removals from building- and user-related energy use, plus other building-related sources of GHG emissions and removals.

The system boundary for the CM1 and CM2 of a building is shown in Table 1 and Figure 1. It consists of the equipment to operate the building fulfilling the demand as energy end use and the technical building system(s) to deliver, convert and generate energy for the energy end use. CM1 and CM2 of a building are determined based on the following:

a) delivered energy for the building and for other energy use within the building's site (curtilage),
b) total on-site energy generated and used in the building and for other energy use within the building's site (curtilage).

Table 1 List of energy end use included in the carbon metric for CM1 and CM2 (DIS 16745)

CM1 only includes Building-related energy use while CM2 includes both Building-related energy use and User-related energy use

	Energy consumption related service
CM1 & CM2 Building-related energy use	• Space heating
	• Space cooling
	• Air movement
	• Domestic hot water
	• Lighting for basic building function (fixed lighting etc.)
	• Auxiliary energy (e. g. for heat pumps)
	• Indoor transportation
	• Building auxiliary devices
CM2 User-related energy use (Examples)	• Plug-in supplementary lighting
	• Household/office appliances
	• Refrigerator
	• Devices in Data Centre
	• Other specific functional devices

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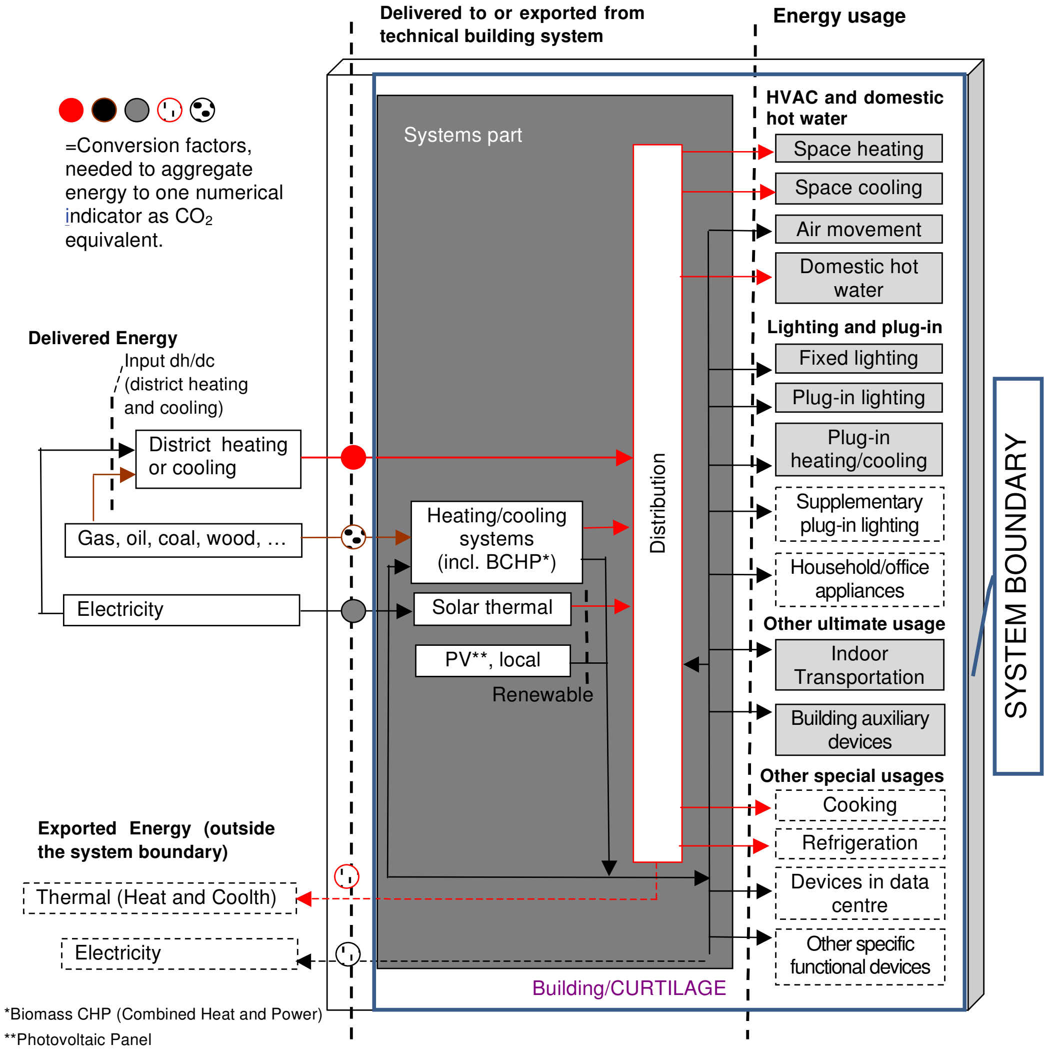

Figure 1 Boundary and energy flows : Main energy flows within and crossing the boundaries for energy use of a building (DIS 16745)

ISO 16734 requires that the system boundary include all the energy consuming and generating systems that are within the building's site (curtilage) and that support operation of the building. All building-related energy end use (as indicated in the pale grey boxes in Figure 1) shall be taken into account for the CM1. Lighting and controls shall be included in the CM1. User-related energy use (as indicated in the dotted box in Figure 1) shall be included in the CM2, including energy for supplementary lighting installed by building users.

Calculation of carbon metric of a building

Carbon metric of buildings, i.e. the emitted mass of GHG expressed as kg CO_2 equivalent per kg emission, is given by the following equation:

$$m\cdot co_{2\mathrm{eqv}} = \sum\left(\left(E_{\mathrm{del,ci}} \times K_{\mathrm{del,ci}}\right) + \left(E_{\mathrm{site,ci}} \times K_{\mathrm{site,ci}}\right)\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

where

$m\cdot co_{2eqv}$ is the emitted mass of GHG expressed as kg CO2 equivalent per kg emission

$E_{del,ci}$ is the delivered energy for energy carrier *ci*,

$E_{site,ci}$ is the energy produced onsite for the energy carrier *ci*,

$K_{del,ci}$ is the GHG emission coefficient for delivered energy carrier *ci*

$K_{site,ci}$ is the GHG emission coefficient for on-site energy carrier *ci*

ISO 16745 recommends to ignore $E_{site,ci}$, in case that the sum of energy produced on-site is estimated to be is less than 2% of the total energy.

Here, energy carrier means substance or phenomenon that can be used to produce mechanical work or heat or to operate chemical or physical processes. In case that the energy carrier(s) provides energy to support the operation of the building and/or other on-site facilities, the measurement of the energy carrier shall take account of all the sources delivered to and generated within the system boundary including electricity, fuels (e.g. gas, oil, wood and other biomass, waste) and imported coolth/steam/heat. It assumes that data for nominal delivered energy is available from utility provider reports and contracts, or electricity bills, or invoices for fuel deliveries, or gas bills, or meter readings, or pipeline measurements and energy management software. Data for the on-site generated energy shall be based on meter readings or the measured amount of biomass consumed (kg).

Energy usage used in the calculation of carbon metrics

For the calculation of CM1 using the equation (1), ISO 167745 mandatorily demands that building-related energy use to be determined by energy for HVAC and domestic hot water (i.e. energy for space heating and cooling, for air movement and domestic hot water), energy for fixed lighting, energy for plug-in equipment (i.e. plug-in lighting, heating and cooling), and energy for indoor transportation and building auxiliary devices.

For calculation of CM2 using the equation (1), ISO 16745 indicates that user-related energy use to be determined by energy for supplementary lighting installed by building users, energy for household/office appliances and energy for other special usages (i.e. energy for cooking, for refrigeration, for devices in data centres and for other specific functional devices)

GHG emission coefficients used in the calculation of carbon metrics

The GHG emission coefficient(s) used in the equation (1) is based on the delivered energy carrier. Respecting on the fact that there does not exist the exclusively universal table of GHG emission coefficient, ISO 16745 mandatorily demands the following information to be stated regarding the GHG emission coefficient used to determine carbon metric by the equation (1): sources of information (e.g., national, international); greenhouse gasses included in CO2 equivalent (e.g., following Kyoto protocol, Montreal protocol, or other protocols); included elements in supply chain (e.g., on-site, or on-site plus upstream processes); time frame of impacts on environment (100 years); and the year of reference of emission coefficient data.

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ISO 16745 indicates that GHG emission coefficients shall be obtained from, in the following order of priority; nationally agreed data; independently provided information; internationally agreed data.

Exported Energy

In ISO 16745, exported energy, i.e. energy produced on-site, but not used for the building or other on-site facilities, is not included in the calculation of carbon metric. However, ISO 16745 accept that export energy is reported as additional information. The GHG emissions from the exported energy is calculated by the following equation.

$$m\cdot co_{2eqv} = \sum\left(E_{exp,ci} \times K_{exp,ci}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

where

$m\cdot co_{2eqv}$ is the GHG emissions from the exported energy

$E_{exp,ci}$ is the exported energy for energy carrier *ci*,

$K_{exp,ci}$ is the GHG emission coefficient for delivered energy carrier *ci*

Reporting and communication of the carbon metric

The carbon metric may be used for a variety of purposes, which can include internal or external benchmarking, public information, property evaluation, policy information asset evaluation, etc.. In order to use and apply the carbon metric appropriately, the reporting of the carbon metric shall include information necessary to describe the building, and give sufficient information to allow traceability and transparency of the measurement. ISO 16745 requires that the carbon metric study report shall include the information shown in Table 2.

Table 2 Information imandatorily included in the carbon metric study report (DIS 16745)

a)	building identification; name of building(s), physical address
b)	type of the carbon metric (e.g. CM1, CM2 or CM3)
c)	value of the carbon metric(s)
d)	value(s) of the carbon intensity(ies) determined
e)	purpose of the reporting
f)	reporting period, 12 consecutive months, mm/yyyy-mm/yyyy (e.g. 7/2013-6/2014)
g)	whether the carbon metric has been normalised to average annualized conditions such as local climate. If yes, include the method used to normalize the carbon metric for average conditions.
h)	date of the evaluation
i)	name of the organisation or individual doing evaluation (self-measurement or third party)
j)	client of the evaluation
k)	description/illustration of the system boundary
l)	list of energy end use included in the carbon metric in relation to the type of CM
m)	whether delivered energy end uses (eg. heating , lighting, cooling etc.) are measured or estimated
n)	inventory of energy carriers
o)	source of GHG emission coefficient (publication, organization, year of the coefficient measured)
p)	year of construction of building (for each building of a complex)
q)	year of latest major renovation affecting energy use (eg. change of HVAC, change of building envelope)
r)	year of any (latest) change in use
s)	total site area
t)	location; country and climate

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Possible usage of CCM in building practices and international trading
CCM defined by ISO 16745 is applicable for international collaboration to reduce GHG emission from buildings. CCM offers a common and widely agreed cornerstone for international policy making on climate mitigation in the building sector (UNEP-SBCI 2009b).

CCM is applicable for benchmarking. CCM could be included as one of sustainable building indicators within overall environmental performance assessment method. In such cases, CCM is used for communication among designers, owners, tenants of the building.

CCM is also applicable for baselining in policy targets, taxation and regulations in local, national and global scale. Policy makers and shareholders could be the users for this purpose. CCM provides the basis for the internationally comparable monitoring of the performance of national or regional GHG reduction programs from building sectors. CCM could enable to evaluate internationally consolidated performance of such programs by consistent aggregation of CCM in each nation or region. In addition, CCM is applicable to the consistent definition of zero emission/energy building in regulations.

It is notable that CCM could provide a common basis for monetize the performance of the reduction of GHG emissions from a building. In another word, CCM enables to define monetary scale of rebates and incentives in economic transactions. Investors, financiers, and real-estate professionals could have opportunities to create new types of carbon trading. For example, CCM could monetize the amount of GHG emission reduction by professional services (e.g. operational energy improvement; retrofitting of existing buildings). Even though building sectors have been believed to be the most significant and effective target of GHG emissions (UNEP-SBCI 2009b), clean development mechanism (CDM) initiatives have excluded building sectors probably due to the lack of measurable, reportable, verifiable (MRV) metric. CCM is exactly MRV metric and could enable CDM and carbon trading in building sectors.

Concluding comments
Because of its simplicity and consistency, CCM provided by ISO 19675 is expected to be practically usable for many stakeholders as a reference for decision making in GHG conscious business activities and governmental policies.

Reference
EN 15978:2011 Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method
ISO/DIS 16745 (2013) Environmental performance of buildings — Carbon metric of a building — Use stage
UNEP SBCI (2009a) Buildings and Climate Change Summary for Decision-Makers (http://bit.ly/1nOxfnW retriviewed on 29 July 2014)
UNEP SBCI (2009b) Common Carbon Metric for measuring Energy Use & reporting Greenhouse Gas Emissions from building operations (http://bit.ly/1lMjSyo retriviewed on 26 May 2014)

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Dynamic material flow analysis of the building stock in Spain

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Abstract: *The building stock must face the growing population demand. However, the building stock growth is subjected to the natural limits of the environment, which depends on its capacity of producing materials and absorbing wastes. For this reason, the future building demand, materials supply, and waste generation need to be projected in the future, for acting towards policies that allow the building stock to be sustainable at social, environmental and economical level.The aim of this paper is to present the future trends in building construction and waste generation through the 21st century in Spain. Based on statistical information and the past activity, the dynamic material flow analysis (MFA) can offer the projections in the building stock, building materials demand, and construction and demolition (C&D) waste generation for the next decades.The dynamic MFA has many valuable applications for the stakeholders in planning dwellings construction, future building materials demand and landfill capacity.*

Construction, demolition, dwellings, waste, projection, building lifetime

Introduction

The building stock must face the growing population demand. However, the building stock growth is subjected to the natural limits of the environment, which depends on its capacity of producing materials and absorbing wastes [1]. For this reason, the future building demand, materials supply, and waste generation need to be projected in the future, for acting towards policies that allow the building stock to be sustainable at social, environmental and economical level.

The future projection can be estimated using the dynamic material flow analysis (MFA). Material Flow Analysis (MFA) is an analytical method of quantifying flows and stocks of materials or substances in a well-defined system [2]. MFA is an important tool to assess the physical consequences of human activities and needs in the field of Industrial Ecology, where it is used on different spatial and temporal scales. Stock dynamics approach was developed as an alternative method for simultaneously forecasting resource demand and waste generation along a period of time [3, 4]. Through knowledge about key parameters determining floor area stocks and flows, and subsequently materials, the model illustrates how knowledge of past activities is reflected in future projections about waste generation and materials demand. The importance of dynamic MFA relies on the prediction of future materials demand and waste generation, and to know in advance the construction and demolition of building stock variation.

Dynamic MFA was initially proposed by Müller [3], who applied it to the dwelling stock in the Netherlands. Later, Bergsdal et al. [4] based on the same model modified it and applied to

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the dwelling stock of Norway. Both analyses adopted the same time period, 1900-2100. The work presented in this paper is based on Saroti et al. [5], who developed the methodology based on these two previous authors. Literature have shown that the dynamic MFA applied to the building stock, material and energy demand, and C&D waste generation in countries such as Norway [4-6], the Netherlands [3], and China [7] presented a pattern behavior. Those experiences showed a very similar trend in the building stocks and materials use: there is a sustained growth along the 20th century, a maximum point at the end of the 20th century and beginnings of 21st century, and a sharp decline along the 21st century. The C&D waste projections can be a valuable source of information to predict the future need for waste treatment capacity, the dominant waste fractions, and the challenges in future waste handling systems [8-11].

The aim of this paper is to present the future trends in building construction and C&D waste generation through the 21st century in Spain. Based on statistical information and the past activity, the dynamic MFA can offer the projections in the building stock, building materials demand, and C&D waste generation for the next decades.

Method

The dynamic MFA is conceptually shown in Figure 1, adapted for the case of study of this paper. The dot line represents the spatial limit of the analysis for the period of one year. Processes are represented by rectangles, while flows are represented by arrows. The analyzed process in this paper is the residential building sector of Spain. The flows express the amount of floor area that in a given period of time (usually a year) enters the stock (new_A), leaves the stock (dem_A), or recirculates inside the stock (ren_A). Therefore, new_A express the new floor area of dwellings, dem_A the demolition floor area of dwellings, and ren_A the renovation floor area of dwellings. They are measured in square meters per year (m^2/y). The net building stock accumulation in the process is expressed by the symbol dA/dt [5].

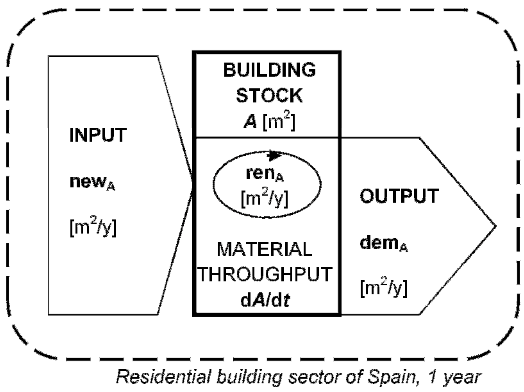

Figure 1. Conceptual model of the dynamic material flow analysis.

The balance equation is given by Sartori et al. [5], which considers that the new floor area, newA, depends on both demolition activity, demA, and additional demand of floor area, dA/dt (equation 1).

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$$\frac{\mathrm{d}A(t)}{\mathrm{d}t} = new_A(t) - dem_A(t) \quad (1)$$

- Population (P): The stock of population and its evolution along the 20th and 21st century are shown in figure 2. According to the official statistics [12], the population in Spain is expected to decrease along the 21st century.

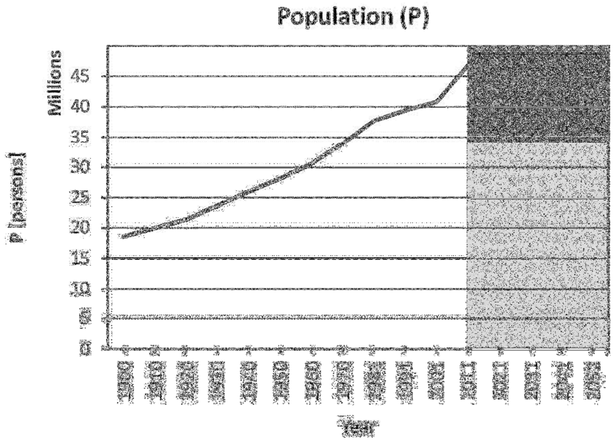

Figure 2. Population in Spain from 1900 to present and population projection until the year 2052 [12].

- Dwelling stock (A): According to Sartori et al. [5], the size of the dwelling stock is driven by the population's demand for dwelling services that satisfy their lifestyle preferences. Therefore, the dwelling stock (A) variation is defined by three parameters; the population (P), person per dwelling (P_D), and the floor area per dwelling (A_D), (equation 2). This data is available, in the case of Spain, for the census of 1991, 2001 and 2011 (Table 1). Since statistics only offer the net floor area, the gross floor area has been estimated by adding 10%. The data projection from 2011 is estimated by using a constant P_D and A_D with the same value than the one offered by the Housing Census of 2011 [13].

$$A(t) = P(t) \cdot \frac{1}{P_D\,(t)} \cdot A_D(t) \quad (2)$$

Table 1. Input data to the model, dwelling census of 1991, 2001 and 2011. Source: INE [13].

Census	P [persons]	P_D [persons/dwelling]	A_D [m^2/dwelling]	A [m^2]
1991	39,433,942	3.31	94.97	1,131,480,123
2001	40,847,371	2.86	98.34	1,404,521,141
2011	46,815,916	1.70	100.14	2,756,631,289

- New buildings flow (new $_A$): The new floor area of the dwelling stock is taken from the official statistics source in Spain, available in the Housing Census of 2011 [13]. The census offers the period of construction of the dwellings. The census 2011 number of dwellings is compared with the new constructed dwellings given by "Visados de obra" of the Professional Architects Association [14] (Figure 3). The average floor area of the total number of dwellings in 2011 (Table 1) is used to calculate the floor area of the dwelling

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stock. This data, together with the period of construction, results in the new building floor area per year (m^2/y), the new buildings flow.

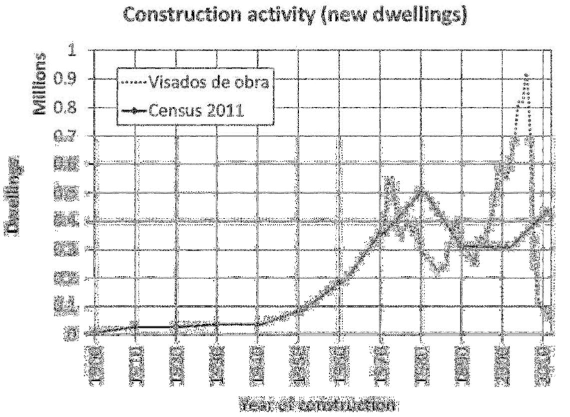

Figure 3. Construction activity in Spain, comparing the year of construction of the dwelling stock existing in 2011 (Census 2011) and the new dwellings constructed from 1970 to 2012 (Visados de obra). Units: Number of dwellings. Source: INE [13, 14].

- Lifetime profile (L): The demolition activity is a function of the previous construction activity and the expected lifetime of a building [5]. Because of this, to calculate the flow of demolished area (dem_A), firstly it is necessary to know the flow of new area (new_A) for all previous years and the corresponding expected lifetime of buildings. For this reason, first of all, it is required to calculate the lifetime profile, which expresses the probability of a general square meter to be found still standing in the stock as a function of time since its construction. Based on Sartori et al. [5], the lifetime profile is estimated by means of the normal cumulative distribution function (cdf), which is defined by two parameters: the mean, τ, and the standard deviation, σ. According to literature [15-17], the expected lifetime of a building ranges 50 to 125 years. In this paper, three scenarios are considered for the mean expected lifetime (τ): low scenario 75 years, medium scenario 100 years, and high scenario 125 year (Figure 4). Moreover, the standard deviation is considered 25% of the lifetime expectancy ($\sigma = 0.25\tau$).

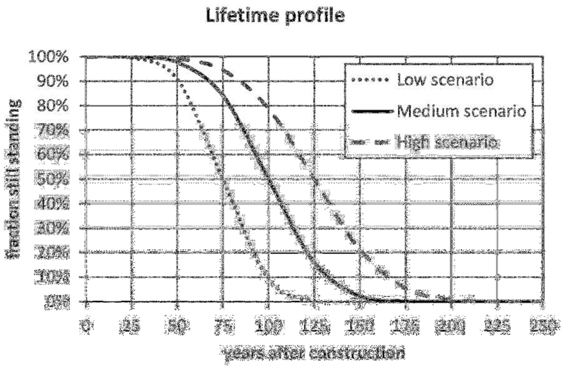

Figure 4. Lifetime profile: the probability of a general square meter to be found still standing in the stock as a function of time since its construction [5].

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- Demolition profile (D): The demolition profile (D) expresses the probability associated with the demolition activity. It is estimated by means of the associated normal probability density function (pdf), which is the derivative of the normal cdf (the previously estimated lifetime profile) [5] (Figure 5).

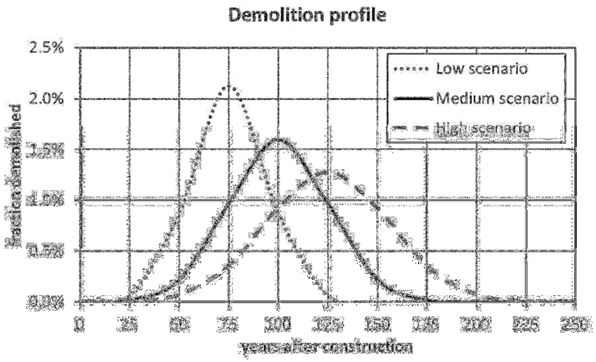

Figure 5. Demolition profile: the probability associated with the demolition activity [5].

- Demolished buildings flow (dem_A): Demolished buildings flow depends on the previous construction flow (new_A) and the probability of these buildings to be demolished and become waste. It is measured in floor area per year (m^2/y). For this reason, the demolished buildings flow is calculated by means of the overlap of these two functions: Demolition profile (D) and Demolished buildings flow (dem_A) [5]. This is done by means of the mathematical concept of convolution. Convolution is a mathematical operator between two functions, *f* and *g*, often denoted as $f*g$. Equation 3 expresses mathematically the fact that the demolition in a specific year is given by the sum of all those constructions from previous years that have now reached their end of life, according to their demolition profile [5].

$$dem_A(t) = D_0(t) + D * new_A = D_0(t) + \int_{t_0}^{t} D\,(t',\tau,\sigma) \cdot new_A(t-t')\mathrm{d}t' \qquad (3)$$

Results and discussion

The evolution of the dwelling stock in Spain (A), the new floor area flow (new_A), and demolition floor area flow (dem_A) have been estimated for the period 1900-2120 (Figure 6). In this first estimation, the stock and flows evolution considers that the construction of new dwellings has stopped in 2011. Therefore, the demolition area is the minimum one that can be found due to the existing dwelling stock in 2011, with no building renovation considered. The renovation flow and the recycling rate of the building components estimations are placed for further research.

Population (P) evolution is a basic driver in the dwelling stock (A) variation. In Spain, population growth in the 20th century has been nearly linear and slightly increasing until 2011. However, in the next decades from present, it is expected a linear decline of the Spanish population. Considering that the two lifestyle indicators are constant along the next decades (P_D = 1.7 persons/dwelling, and A_D = 100,14 m^2/dwelling), the building stock is consequently declining with the same rate than population. Thus, the construction activity, which has

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presented a constant increasing trend along the 20th century and a sharp increase in the 2000's decade, is expected to decline from 2011 to 2052, according to population demand. In 2011, the building stock in Spain presents a remarkable building stock constructed in the 1970's and in the 2000's decades. The peak of construction in these decades will produce a peak of demolition activity towards the end of the 21st century.

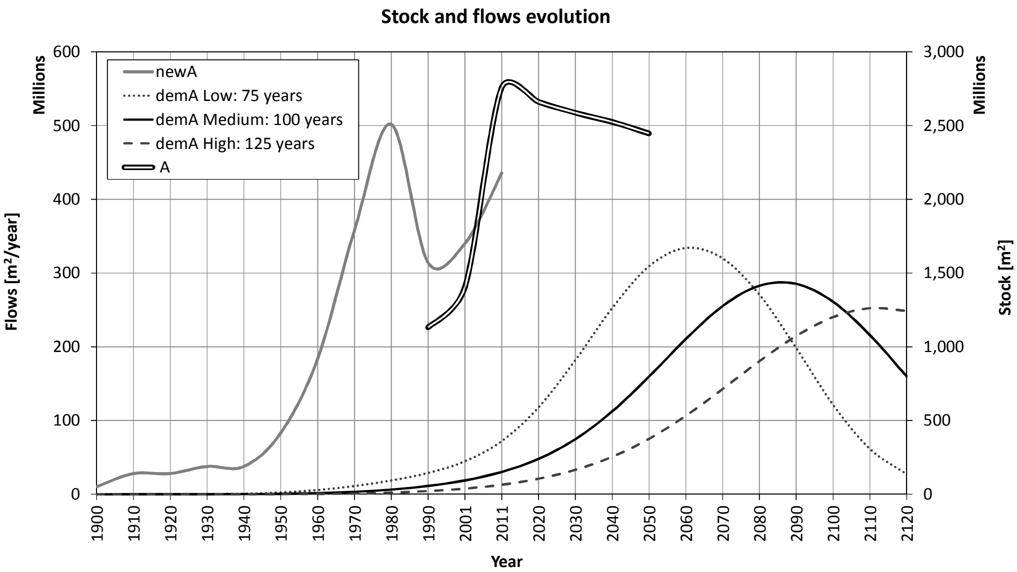

Figure 6. Stock and flows evolution from 1900 to 2120 of the dwelling stock in Spain, for the three scenarios of building lifespan (low=75 years, medium=100 years, and high=125 years).

The three demolition flow scenarios are shown together in Figure 6. The alterations of the lifetime assumptions influences the demolition peaks. The low scenario, which considers a probabilistic lifetime of 75 years, presents a maximum demolished dwelling area in 2060, with 334 Mm^2. The medium scenario, with 100 years, presents the maximum in 2090, with 285 Mm^2. Finally, the high scenario, with a 125 years lifespan, presents the maximum amount in 2110, with 252 Mm^2.

In the extreme case that no more new buildings were ever constructed again, the demolished building area would grow up to a point reaching a demolished area 10 times bigger than today's demolished buildings. On the other hand, the increase in the demolition activity would produce in turn an increase in the construction activity to substitute the demolished floor area. However, the decline of the building stock demand in the 21st century, due to the population declining, would cause a lower construction activity.

Conclusions

The dynamic MFA presents the built environment as a dynamic system where past activity levels strongly influence future development. The methodology allows predicting the future demolition activity based on the past construction activity, and the projection of the residential building stock. The stock projection is based on the population growth and lifestyle. The construction activity is based on the period of construction of the existing

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building stock in 2011. The demolition activity projection is based on the previous construction activity and the probabilistic lifetime profile of the building stock. Three scenarios of building lifetime have been assumed; low (75 years), medium (100 years), and high (125 years).

The results show a significant increase in the demolition area in the next decades and, as a consequence, in the C&D waste generation. It will reach a top along the second half of the 21st century, in 2060 for the lowest building lifetime scenario, in 2090 for the medium, and in 2110 for the highest. If no building renovation or materials recycling measures are taken, the C&D waste generation is expected to growth alarmingly, up to an amount one order of magnitude bigger than today's C&D waste generation.

The implementation of the dynamic MFA in the Spanish building stock has many valuable applications for the stakeholders regarding materials demand, waste generation, and energy conservation. These applications are; (1) Planning medium and long term strategies in new dwellings construction according to lifestyle population based on the number of persons per dwelling and floor area per dwelling. (2) Estimating future scenarios of construction materials demand according to the dwelling stock variation. (3) Planning the landfills capacity in a region, and the possibilities in the recycling, re-use and recovery of the C&D wastes as raw materials for other industrial sectors.

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Session 142:

Which are the limits of life-cycle assessment as a rating tool to evaluate sustainability in building? (III)

Chairperson:

Macías, Manuel

Profesor/Responsable del área de Investigación. Universidad Politécnica de Madrid/GBCe

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Contribution of timber buildings on sustainability issues

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Abstract: *In the building sector, discussions on climate change used to focus on energy efficiency, but now the focus has broadened to sustainability of materials. Increasing energy efficiency in the operation phase shifts the focus on primary energy consumption of production. Actual research results on LCA-calculations in life cycle with a focus on wooden products are shown in this paper. Calculations of timber buildings have specific properties in comparison to other materials. These are carbon storage and primary energy as material inherent property. To make the advantages of timber products visible it is important to show the LCA calculations in a transparent and comparable way. Therefore in Europe new standards EN 15978 and EN 15804 were developed. Timber buildings have the specific property of storing carbon temporarily in its material. But for future long-term and resource efficient use of wood of premium qualities is necessary to ensure sustainable construction with wood, long lifespan and cascading of wooden material.*

life cycle assessment, carbon-storage, renewable primary energy, end-of life

1. Introduction

The building sector has been identified as a major contributor to environmental impact. In the context of sustainable development, an optimization of environmental impact during a building life cycle is significant target. In building sector discussions on climate change used to focus on energy efficiency as it is seen as the main indicator where reductions of CO2 emissions can be obtained. With the introduction of the nZEB-directive in Europe the goal is to reduce the CO2 emissions of all new buildings to nearly zero by 2020. When that is achieved further reductions can be realised by shifting the focus on the materiality of construction. Reductions of CO2 emissions can be influenced with the choice of material. Through that renewable material and material with low CO2-emission come into focus.

1.1 General

In the last decades the operation has been regarded as the most dominant phase in the life cycle of buildings in terms of energy consumption resulting in greenhouse gas emissions. Here energy standard of the building envelope interacts with the energy consumption in the operation phase and the used energy sources. It has been stated that the operational phase accounts for more than 70% of life cycle energy use of a building in many cases [1,2,3,4] As a result of the effort for reducing the operational energy the importance of the other life cycle stages has increased [3]. The choice of material used for buildings and its impact on the environment during the whole production process becomes an important factor together with the replacement of material in lifecycle. Various own calculations on life cycle analysis show that the operational phase accounts for around 45 % to 80% in buildings, depending on the energetic standard. Or in other words 20% to 55% of CO2 emissions could be influenced by materials used for building. Our calculations were made according to German datasets (ökobau.dat) and calculation rules applied for sustainability certification projects in Germany.

As a common agreement in some European research projects (ECO2, openhouse) lifecycle was regarded as 50 years. But thinking in lifecycle not only applies to construction and operation of buildings. Also maintenance, replacement cycles and repairs are important issues, which have a significant input in lifecycle calculations. Maintenance in operational phase also plays an important role for calculations in life cycle. As maintenance highly depend on durability of material and the exchange rate of building parts, it has a big influence on lifecycle assessment. For maintenance clear agreement is necessary what is calculated and how calculations are made to make results comparable and to emphasise certain material aspects. Wood as a renewable material can play a vital role in reducing greenhouse gas emissions. Main advantages of wooden material are the possibility of storing carbon in the material over a certain time period (carbon storage) and containing primary energy as material inherent property. The existence of sustainable forestry is preconditioned.

1.2 Examples on lifecycle of wooden buildings

Life cycle analysis is an important tool to measure environmental properties of constructions in the life cycle of a buildings. Here investigations are important on material production, operation of the buildings over a certain time period and end-of-life scenarios. Various research has been conducted on lifecycle of wooden buildings, but is highly dependent on database, system boundaries and energy mix. Calculations mainly state LCA results in input / output categories per m² of gross floor area and per whole building. Additional results show the amount of wood used in the building, the temporal carbon storage, and the classification of primary energy (PE) in renewable and non-renewable parts. For renewable primary energy it is important to subdivide further in the categories of PE renewable for energetic use and PE renewable for use as raw material (material inherent property). Recently published data by König [5] state that buildings in wood have 58% to 71 % lower greenhouse gas emissions than mineral buildings. These constructions are calculated over a lifespan of 50 years, with database ökobau.dat and calculation tool legep. Beside that these numbers include construction, operation and maintenance. Also primary energy non-renewable is around 50% lower than in mineral buildings. The share of primary energy renewable is up to five times higher than in mineral buildings – this is due to the fact of the heating value of wood which is included in that primary energy calculation. In End-of-life status wood shows benefits as energy source but also the greenhouse gas emissions for burning the material have to be calculated.

1.3 European standards

With the introduction of standard EN 15804:2012 [6] on product level and EN 15978: 2011 [7] on building level lifecycle can be divided in modules production (A), operation (B) and end-of-life (C). This order is helpful for comparative studies. The state-of-the-art standards, EN 15804 and EN15978, provide general calculation rules for building LCAs, which need to be clarified now. The standards define the linear life cycle of a building, which consists of four main stages (module A, B and C) and additional information module D. For the first time this standard gives a clear rule how to calculate comparable LCA. They bring transparency in issues of life cycle inventory like system boundaries, division in included subcategories and

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so on. However, the rules for comparative assessment have not yet been achieved fully. Therefore further harmonization activities have been carried out actively nowadays [8,9]. In the standard there is a subdivision of the input categories PE renewable and PE non-renewable in each case two categories of primary energy (renewable or non-renewable) as energetic use or for use as raw material. This subdivision is the first step to clarify the specific characteristic of wooden material. Extensive datasets for wooden products in Germany have been calculated by [10]. Following this standard shall help to clarify calculation comparability and included end-of-life scenarios. This is important for the wood sector, because it gives clear rules on how to count material properties like heating value. It shows clearly where the advantages of wooden products are. Module D can show the substitution potential of wood for energetic use and for recycling. Also carbon storage capacity can be shown here, there are also discussions on showing carbon storage in module B1.

2. Actual research results

In this chapter actual research results are shown. They start with the finished woodwisdom ECO2-project, then summarize various LCA-calculations on lifecycle of wooden buildings and end with end-of-life observations.

2.1 Outcome of the research project ECO2

Wood in carbon efficient construction – or "€CO2" - has been a WoodWisdom-Net research project (2010-2013). Main outcome of this part of the project can be summarized as:

- System boundaries for practical LCAs of whole buildings were defined, as shown in figure 2. They show the system boundaries for practical LCA calculations on building level and are in line with EN 15978. Providing a clear description of the assessment processes and results are fundamental requirements.

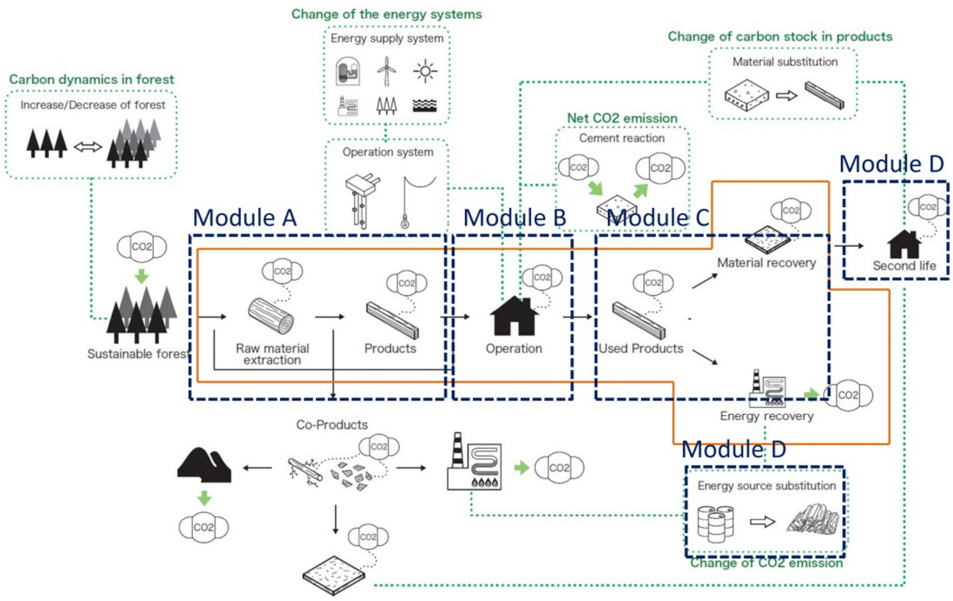

Figure 1: Holistic picture of carbon footprint related to a wood-based building system and simplified system boundary (red line) for the system building including only direct environmental effects. [11]

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- The project outlines the importance of the design phase for low carbon wooden houses and evaluates the influence of the construction phase as well as different production phases (on-site versus off-site).

A focus was made on calculation of module A. Here construction process was examined and on-site versus off-site construction compared. [12] The construction phase (A4,A5) itself had minor environmental input on the reference buildings compared to material side (A1-A3). Prefabrication (off-site construction) seems to be a slightly more environmental friendly way of building than on-site construction. Transportation of the buildings components has relevant impact. Furthermore the project demonstrated the influence of transportation and waste management, the influence of use and maintenance phase as well as the influences of end-of-life phases for wooden materials. Systematic design process needs to be developed so that the buildings can contribute to reductions of greenhouse gases and primary energy use. [11]

- For one exemplary building in Mietraching, Germany, results on building level are shown. LCA has been conducted for material production, construction, and operation phase of the building. The Mietraching building is a four-story apartment building located south-east of Munich. The energy standard of the building is 64 kWh/m²a; the gross floor area is 726 m². In total the amount of stored carbon is nearly 209 t of CO_2 eq. Most carbon is stored in the primary construction of walls, floors and roof, also the energy content (PE renewable for material use) is highest there. Cladding, windows, interior design in wood bring only small additional positive inputs.

In terms of building elements the basement is dominant regarding carbon footprint due to its volume and mass for the material production phase (A1-3). Here greenhouse gas emissions are highest.

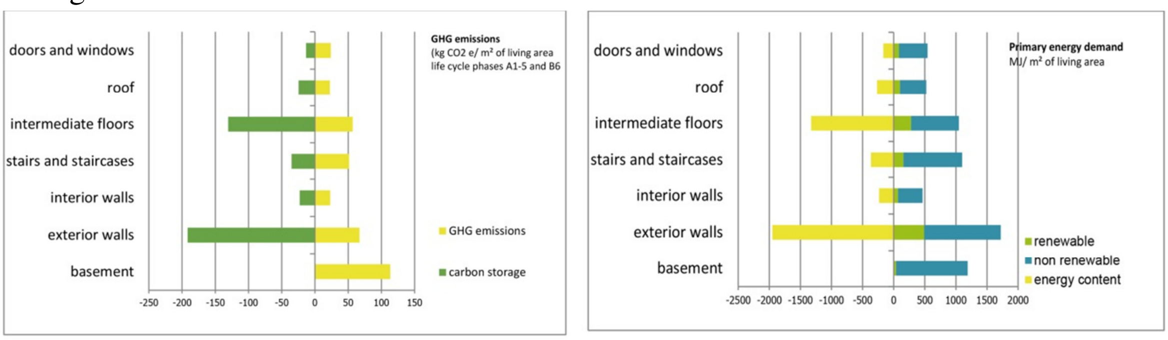

Figure 2: Primary energy demand and greenhouse gas emissions from Mietraching building [11]

High greenhouse gas emissions also come from exterior walls and floors. This is due to mineral wool insulation and layers of gypsum board. On the other hand exterior walls and floors are the elements which have a high amount of carbon stored. The carbon storage exceeds the greenhouse gas emissions if combined and create a negative value in module A. Primary structure for buildings out of wooden material increases the carbon storage of building significantly. Other buildings calculated in the project showed the same results.

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2.2 LCA of wooden buildings

Further research was conducted by calculating wooden buildings in their life cycle – from production of material to end-of life for other buildings. The buildings were compared over a life cycle of 50 years and with the dataset of ökobau.dat (Germany).

The semidetached wooden house for two parties in Ebersberg, east of Munich, was made of massive timber (CLT) on a concrete basement as foundation. The energy standard of the building is 50 kWh/m²a; the gross floor area is 558 m².
LCA calculations show similar tendencies as shown in the Mietraching building described before. The building stores 141 t of $CO2$ eq. in its material. Main primary energy non-renewable is found in the basement, but also exterior walls and floors / roof made of CLT as primary structure have high amount of PE non-renewable, due to the production process and the additional construction layers with other materials (like gypsum board, foil) in the construction, see figure 4. The amount of greenhouse gas emissions shows similar distribution. Highest emissions come from the basement which is followed be walls and roof. Looking at the percentage of renewable material in this building is can be said, that 43% of whole volume (m³) is wooden material; in mass (kg) it is only 17%. This shows clearly that even in buildings which are seen to be "wooden houses" there is a high proportion of non-wooden material.
In a next step, it was researched how the LCA results would change if as much material as possible is made from timber. This means for that building that all flooring was calculated as parquet, all massive timber walls and ceilings inside are left visible and not cladded with gypsum board), roof is cladded with wooden shingles and only wooden windows are used. Results show that all these inputs do not have high influence on calculation result. The result only changes by less than 5 %. On the other hand the same building without a basement (and only small concrete foundation) has very high influence. Change from same building with and without concrete basement make a difference of 25% in PE non-renewable or approx. 35% in greenhouse gas emissions. This shows the importance of early planning stages. The environmental impacts of the building construction can be largely influenced through decisions on basement and primary structure. Generally wooden buildings store carbon as a temporal carbon storage which will end when the building is recycled for energetic use. The carbon storage can be prolonged if the wooden material is reused rather that burned.

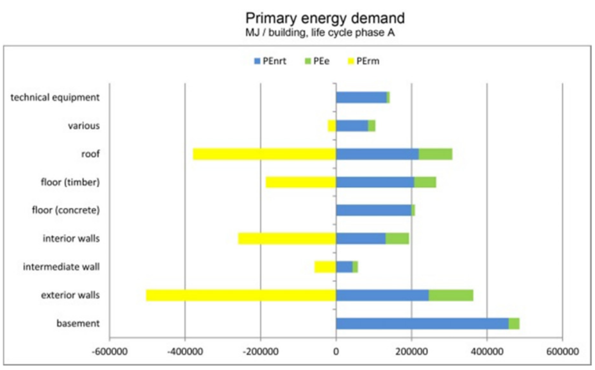

Figure 3: Primary energy demand for semidetached house in Ebersberg

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Overall results show that wooden buildings have slightly higher PE renewable in life cycle (module A-C) and a much higher PE renewable in production phase (module A) only, due to embedded energy in wooden products. Carbon storage is at least 10 times higher than in mineral buildings. The greenhouse gas emissions results as the output of production and construction phase of buildings and the operation of buildings. Greenhouse gas emissions are smaller than mineral buildings, due to carbon storage. Discussions are going on on how to show carbon storage in line with EN 15978. The indicator primary energy renewable as material property indicates the heating value bound in the timber structure. It can be used as energy source later or as recycling material. Thinking the principal of sustainability further building wooden houses could give future generations the possibility to gain values when the building is replaced. The wooden material could then generate value as energy source or if construction is made accordingly and without chemical treatment be reused as material. Building timber houses therefore is a good way to proceed in sustainability issues.
Building large and high rise timber buildings need to fulfill specific regulations regarding fire safety and noise protection and so on. This leads to the use of high amount of for example gypsum board. This has a strong influence on LCA of construction phase and cannot be neglected. Calculations show that wooden buildings have in between 30 - 45% of renewable material (in kg) per m² of gross floor area in mass. In contrary buildings of mainly massive materials have only 5% of renewable material (in kg) per m² of gross floor area.

2.3 Considerations on end of life status

Scenarios on end-of-life calculations are important to improve LCA further and to increase resource efficiency of material flows. With a growing importance of wood as significant biomass component of the renewable energy supply, there could be a shortage in the availability of wood at reasonable prices in the future. Already in Europe prices for wooden raw material have risen. For that systematically examinations of availability of wooden material for reuse and recycling have to be done. A better management of the renewable resources would help the wood sector to ensure a long-term availability of solid wood products. The advantage of wood for carbon storage can be obtained through reuse and recycling of the material. In general the demand for reclaimed wood products in the building sector will rise due to the fact that the thermal use of wood should only be the last option in the cascading. The refinement of reclaimed wood for innovative products as well as the broadening and enhancement of the cascades of reuse and recycling is strongly needed for the timber construction industry. For reuse of wooden material, it is important to make sure no contaminated wood is used.

3. Conclusions

Increased energy efficiency in use phase facilitates a reduction of the carbon footprint. Therefore primary energy consumption of constructions and its impacts are emphasised. Wooden constructions have various positive effects in terms of sustainability. Wooden buildings store high amount of carbon temporarily. Wooden buildings therefore can be seen as temporal carbon storage. If cascade use of timber construction is developed further this timeframe can be prolonged. Although wooden buildings contain only around 30% of renewable material (mass) this is a high percentage compared to mineral buildings. In general wooden buildings have lower greenhouse gas emissions in construction (module A) and a high share of primary energy renewable bound in material (heating value). Additional calculations of timber buildings in life cycle show benefits in lower abiotic resource depletion which could get an important factor for resource efficiency in future.

A more in depth activity with environmental properties of timber buildings is necessary in order to create benchmarks for promoting timber constructions and highlight the advantages of wooden materials in building sector. Wooden construction could be promoted by defined reference C-values already in stage of real estate sale. The advantages of wooden buildings already help some investors and communities to invest in wooden buildings. For example the city of Munich is currently planning an ecological residential estate on an old military convertion site with around 500 flats. Focus is to link the selling of building plots to the agreement to build with wood. A research project funded by the DBU – Deutsche Bundesstiftung Umwelt - was started in summer 2014 to create reference values for the agreements with ste ownerregarding greenhouse gas emissions, primary energy and mass of renewable material. The implementation of these values then get monitored in the project and planners adviced to reach the agreed benchmarks and also be in line wit building regulations (fire safety). This method could be a possible help rising the percentage of renewable material in building sector. To show the vital influence of wooden buildings to global climate reduction goals, it is necessary to quantify the substitution potential of wooden buildings country wise.

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Influence of construction material choice and design parameters on greenhouse gas emissions of buildings

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Abstract: *Wood has typically lower environmental impacts compared to other materials. However, it also has reduced capacity to store thermal energy, potentially causing increased operating energy demand. Here we investigate this trade-off between environmental impacts of the construction and operating phase and examine key factors determining the overall environmental performance. To do so we couple a sophisticated building simulation with a life cycle assessment tool. We investigate a massive and a wooden variant of a single-family home. Sensitivity is analysed by altering ten different input parameters, using upper and lower extreme values. We find that the influence of building thermal inertia on annual energy demand is relatively small, but may become significant when the building service life is taken into account. In general, impacts from building operation outweigh material-related ones. Accordingly, parameters affecting energy demand (e.g. ventilation rate) are most influential. Since massive and concrete buildings react differently to changes in different parameters, we recommend individual design strategies for each building variant.*

Keywords: building simulation, thermal inertia, embodied energy, life cycle assessment, wood construction, sensitivity analysis

Introduction

Swiss policy makers are looking for ways to stimulate increased wood use in the construction sector. Some cantons even require planners to consider a wooden alternative, when tendering out public buildings. However, wooden buildings may have a reduced capacity to store thermal energy, which may counteract the ecological advantages of the construction phase.

Figure 1 illustrates the effect of thermal inertia for massive walls (left) and different coverings for a massive wall (right graph). Massive walls of 15 cm thickness have about four times higher areal heat capacity, compared to wooden walls.[1] This may result in increased space heat demand of wooden buildings, offsetting environmental benefits due to construction material. This paper illustrates the life cycle greenhouse gas emissions (GHG) of a wooden construction, compared to an equivalent massive building. Furthermore, we vary ten different parameters between upper and lower extreme values in order to analyse the sensitivity of each building type.

[1] Areal heat capacity X_i is calculated based on ISO 13786 (T=24h, $R_{si/se}$=0.0). Material properties are according to EN 12524.

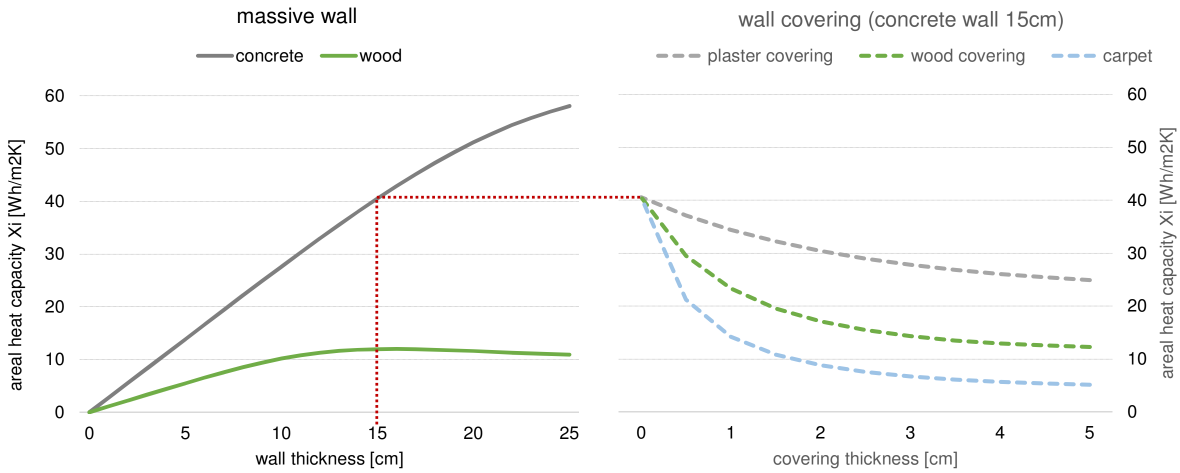

Figure 1 Thermal inertia of massive walls (left graph) for concrete (grey line) and wood (green line) and effect of wall covering (right graph). The red dotted line describes how thermal inertia of a 15 cm concrete element will change, when covered with different materials (dashed lines).

Method and model

To investigate the life-cycle implications of thermal inertia in building mass, a 200 m^2 single-family home (SFH) is modelled. The building is document in Müller et al. [1] along with four different construction variants (3 wood and 1 brick), typically found in recently built Swiss single family homes. For this analysis, the two extreme scenarios (in terms of thermal inertia) are used for the energy simulations. For the massive building, the exterior wall consists of 15 cm bricks, 18 cm thermal insulation, and interior plaster. The wooden exterior wall is more complex: interior plaster, vapour barrier, 22 cm thermal insulation (90%) / wood frame (10%) construction, medium density fibreboard, and a ventilated wooden façade. Furthermore, also roof, slab, and interior elements have different compositions in each variant. All other parameters, such as thermal transmittance (U-value), floor area, etc., are identical in the two variants. For both variants, input parameters are varied to investigate the respective sensitivities (see Table 1). The functional unit for the building variant comparison is “one single family home with 200 m^2 floor area and with a service life of 90 years”.

A newly developed program is used for the model calculations, using different software and Python modules, such as brightway2 [2]. Space energy demand is determined by an external dynamic simulation software (energyplus v8.1), using occupation and load profiles, as in the Swiss documentation SIA 2024 [3]. Loads from occupation, lighting and appliances are taken from the Swiss standard SN 520 380/1 (2009) [4]. The construction material accounted for is building envelope and interior walls for the entire building service life, including production, replacement, and disposal. Building foundation, roof covering, interior equipment, electrical and sanitary equipment are not included yet. Building service life and material replacement are based on SIA 2032 [2],[2] a documentation providing calculation guidelines on embodied energy in buildings. All life cycle inventories (LCI) either stem directly from the LCI-

[2] Service life durations are not used directly, since they are described as “*payback periods*” and therefore assumed from an economical point of view.

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database ecoinvent v2.2 [3] or are based on it. For material disposal the most adequate ecoinvent disposal process is selected for each material (i.e. normally "*…to sorting plant*"). In this study, results are provided in terms of greenhouse gas emissions [4][3] for energy demand and construction material, extrapolated to the building's entire life cycle.

Table 1 illustrates the scenarios and sensitivity parameters. The column with 'typical' values represents inputs of the two base cases. Each parameter is applied, for both extremes (lower and upper value), on both baseline scenarios, i.e. wooden and massive building variant. For each sensitivity parameter, only the parameter in question and the construction materials for each material variant are replaced. All other inputs remain as given in the column 'typical value' in Table 1.

Table 1 Overview of simulation input parameters, with lower, typical, and upper value for each sensitivity parameter

Parameter	**Indicator [unit]**	**Lower value**	**Typical value**	**Upper value**	**Impact on**	
					energy	**material**
Thermal inertia (baseline scenarios)	X_i [Wh/m²K]	4.0 (wood frame)	none	12.3 (massive brick)	X	X
Climate data – Degree Days	$HDD_{20/12}$ CDD_{18} [Kd]	Lugano (2567 HDD, 281 CDD)	Zurich (3234 HDD, 148 CDD)	Davos (5864 HDD, 0 CDD)	X	-
Window ratio	% of façade area	10%	14 %	60%	X	X
Shading – window overhang	Length [m]	0.0	0.3	1.0	X	-
Ventilation rate	n [m³/m³h]	0.3	1.0	2.0	X	-
Internal load	[W/m²] (mean)	6.8	2.9	14.6	X	-
Heat generation	energy carrier	Oil heating, non-condens.	Gas heating, condensing	Ground source heat pump	X	partly
Heating setpoint	T_h [°C]	17	20	23	X	-
Cooling setpoint	T_c [°C]	28	25	22	X	-
Thermal resistance	Insulation thickness [%]	50%	100%	200%	X	X
Window solar transmittance	g [-]	0.20	0.57	0.80	X	-

Results

Figure 2 illustrates the results of the sensitivity analysis as carried out using the parameters in Table 1. Results are presented here as total greenhouse gas emissions for material (production, replacement, disposal), space cooling and heating demand over the entire service life of the building. In the following section, results presented in Figure 2 are shortly described.

As can be seen in Table 1, the two **baseline scenarios** (low and high inertia), differ by a factor of three in their total areal heat capacity, i.e. X_i = 4.0 Wh/m²K and X_i = 12.3 Wh/m²K

[3] IPCC 2007 100a [4]

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respectively.[4] This difference in thermal inertia slightly influences the results in space heat demand. The lightweight variant has an increased annual space heat demand of 55 kWh/m^{2}a, compared to the heavyweight variant with 53 kWh/m^{2}a. Space cooling demand is in the wooden variant 13 kWh/m^{2}a, thus 28% higher than the massive variant with 10 kWh/m^{2}a. Analysis shows that it is in particular during the intermediate seasons (i.e. spring and autumn) that the high inertia variant has more autonomy, therefore requiring less thermal energy input to maintain the desired indoor temperature. However, the amount of embodied energy differs by a factor of two: 36 t CO_2-eq.and 72 t CO_2-eq. for the wooden and massive base scenario respectively (two left-hand bars in Figure 2). The total lifetime greenhouse gas emissions of the massive building is composed of the following: 72 tons (21%) materials, 11 tons (3%) cooling, and 265 tons (76%) heating. For the wooden scenario, the relationships change: 36 tons (11%) material, 15 tons (4%) cooling, and 275 tons (84%) heating. Thus, the wooden scenario yields an overall slight advantage of 7%, due to advantages in construction material. Total material mass of the wooden variant is approximately one third that of the massive building.

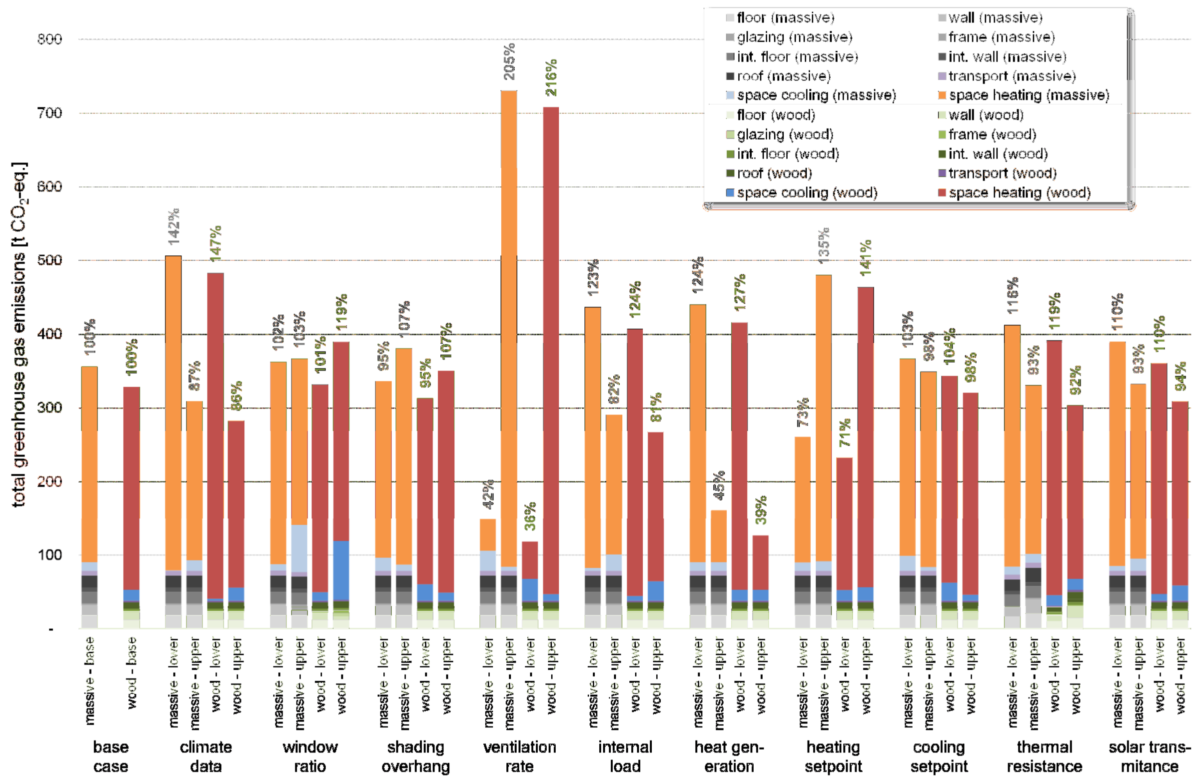

Figure 2 Total greenhouse gas emissions in tons CO_2-equivalents. Each bar represents one sensitivity run for material variant (massive and wood) and lower, upper value assumption as given in Table 1. Percentages above the bars relate to the respective base scenarios on the left-hand side (grey: massive, green: wooden).

The **climate data** has an important impact on the lifetime performance of both building types. The colder climate increases space heat demand to 86 kWh/m^{2}a (massive) and 89 kWh/m^{2}a

[4] Areal heat capacity X_i is calculated based on ISO 13786 (T=24h, $R_{si/se}$=0.0). Material properties are according to EN 12524.

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(wooden), respectively. In the colder climate of Davos, the massive building variant has practically no more space cooling demand. The warmer climate (Lugano) reduces space heat demand to 43 kWh/m^{2}a (massive) and 45 kWh/m^{2}a (wooden). Space cooling demand increases slightly for both the massive (25%) and wooden (19%) variant. Overall greenhouse gas emissions may increase by as much as 47%, this effect being more pronounced for the wooden building. In fact, this 'upper' scenario is the only parameter where total greenhouse gas emissions of the wooden scenario will surpass the ones of the corresponding massive scenario.

A change in **window ratio** has several effects, which partially cancel each other out. Therefore, only moderate changes in total greenhouse gas emissions are observed. Smaller window areas result in increased space heat demand (less solar gains), as well as in reduced cooling demand. Larger window surface actually reduces the material impact of the massive building by 2%, because of the relatively lower embodied energy in windows, compared to bricks. For the wooden building the opposite effect is observed – larger window surfaces result in increased overall material impact of 3%. These effects mostly compensate one another. Only the wooden building has significantly higher greenhouse gas emissions for the 'upper' scenario, due to increased space heat demand.

Window overhang (shading) has a similar effect. The more overhang depth ('upper' scenarios) a building has, the lower the solar gains, and accordingly the higher space heat demand will be. This is contrary to changes in cooling demand, i.e. the more overhang, the less cooling demand. Overall, smaller overhangs will have a slightly beneficial effect for both scenarios – at least for the (relatively moderate) climate of Zurich. Results would certainly be different in warmer climates. The material fraction of overhangs was neglected here.

Typically, the **ventilation / design flow rate** has an important effect on a building's space heat demand, therefore also affecting greenhouse gas emissions (building life 90 years). It should be noted, that the 'lower' scenarios represent extremely energy-efficient buildings (ca. 10 kWh/m^{2}a, comparable to passive houses), since the base scenario already has very good thermal insulation. Relatively moderate changes in air change will result in an increase in total greenhouse gas emissions by a factor of two. The result is more pronounced for the wooden building, underlining the effect of thermal inertia. The more thermal mass a building has, the better it will be able to maintain the temperature during ventilation periods (e.g. window opening). In the case of cooling, however, this can be a disadvantage.

Internal load / gains also have an important effect on space heat and cooling demand. Low occupation and gains from appliances and lighting, will strongly affect space heat demand, resulting in approximately 20% increased greenhouse gas emissions. Highly occupied scenarios have very low space heat demand, but significantly higher cooling energy demand. The overall effect on greenhouse gas emissions was found to be in the range of ±20%, being slightly higher for the wooden variant.

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The choice of (space) **heat generation** has an important effect on the overall greenhouse gas performance of buildings. Dated non-condensing oil-based burners have approx. 30% higher greenhouse gas emissions than the condensing gas boiler in the base scenario. The result in the 'upper' sensitivity parameter is also a result of the clean Swiss electricity mix, used to drive the heat pump. Lifetime greenhouse gas emissions are affected quite considerably (minus 60%), especially for the less CO_2-intense scenario of the heat pump. It is important to note that, at least in the case of the massive building, greenhouse gas emissions of materials become almost equally important as operating energy demand.

Heating setpoints, respectively indoor temperatures, influence space heat demand considerably. A reduced temperature of 17 °C (compared to 20 °C in the base scenario), will cut overall greenhouse gas emissions by approximately one fourth. 3 °C higher temperature leads to 35% (massive) and 41% (wooden) increased total emissions. The wooden building seems to react more to changes in this parameter, since often larger temperature swings occur. The 'upper' scenario also causes a considerable increase in cooling demand for the wooden building, since the wooden building generally has a higher tendency to overheat.

Analogously, the **cooling setpoint** affects space cooling demand by 2 to 4 percent, depending on the scenario. Accordingly, total emissions will be affected by 2-4%. Again, here the wooden building's tendency to overheat will make this effect more pronounced for the 'upper' wood sensitivity parameter.

Varying the **thermal resistance**, and consequently the amount of thermal insulation, will affect both scenarios similarly. Since the base scenario is already very well insulated, the effect on the 'upper' case is relatively small (8%). As seen for the parameter of ventilation rate above, energy efficiency measures usually have a slightly larger effect on the wooden case. These results indicate that savings in GHG emissions from space heating usually compensate impacts due to the additional insulation material – even in very efficient buildings.

The **solar transmittance** or heat gain coefficient (also g-value) shows similar effects, as observed for the window ratio or shading overhang, above. In addition, here the amount of solar gains increases with an increasing coefficient. At 6-10%, the overall effect is relatively small. However, it should be kept in mind that the base scenarios have a relatively low window ratio of 14%. Again, the wooden building exhibits significantly increased cooling demand. The material aspect of this parameter has been neglected here, although a change in g-value may be a result of the number of window panes.

Comparing the results for the different sensitivity parameters yields that impacts from energy demand are usually substantially more important during the building's lifecycle than from material. This is especially true for the wooden variant, which will therefore profit comparatively more from any reduction in energy demand. The material-energy relationship has been shown by several authors in recent years (e.g. [5], [6]). However, this trend is reversed and material impact becomes practically as important as operational energy

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consumption, when looking at extraordinarily energy-efficient buildings or buildings with clean energy production.

Discussion

We were able to investigate some important drivers for greenhouse gas emissions of wooden and massive buildings. As illustrated above, wooden / low inertia buildings have some particular properties, in terms of thermal behaviour and lifetime environmental impact. Therefore, it is important to pay special attention to those aspects when designing wooden buildings. In particular, aspects, such as, ventilation (airtightness) or overall energy demand should be considered more carefully when choosing low thermal inertia constructions. Since cooling demand tends to be high in wooden buildings, also good shading systems are important. Large window surfaces should be avoided for the same reason and due to the additional material impact. For massive buildings, special attention should be paid to the selection of the construction material, respectively its environmental impact. The results are mostly in line with the findings in similar studies. For example, Doodoo et al. [7] also find that the impact of difference in thermal inertia is relatively small and that, in contrast, the advantage due to the material component in wooden buildings is far more important. Here we show results only for one environmental impact indicator (i.e. greenhouse gas emissions). However, for other indicators the findings may differ considerably. For instance, when considering total cumulated primary energy (not presented here), the massive base variant performs slightly better than the wooden equivalent. We intend to consider further indicators in a future publication.

Outlook

The results, presented in this paper, represent the first findings of a parametric study. A journal publication will be submitted in the course of 2014 and include further parameters, as well as a numerical sensitivity analysis. Further aspects of building life cycle demand (such as service life, transport, hot water demand, electricity demand and mix, material disposal) will most likely have similar impact on the building's lifetime performance.

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Light Concrete Frame for Sustainable Buildings

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Abstract: *Paper presents partial results of long-term research of a new optimized subtle precast construction system based on high performance silicate composites. The system is particularly aimed for building construction in passive or zero-energy standard. Subtle structural elements from HPC can be integrated into building envelope of energy efficient buildings with significant reduction of envelope structure and avoiding risk of thermal bridges. Significant advantages of subtle elements are material and energy savings during production, transport, manipulation and construction on building site.*

A complex LCA analysis of various RC frame structures is presented and environmental impacts are compared and discussed. Performed complex LCA is based on local environmental data collected within the inventory phase of the LCA procedure. The results show that it is possible to reduce environmental impact in comparison to common solution (cast in site RC frame structure) due to excellent mechanical properties of HPC that enables realization of subtle structural elements.

Light concrete frame, optimization, High Performance Concrete, life cycle assessment, prototype

Introduction

High performance concrete (HPC) has become an effective tool on the turn of the millennium that enables due to its technological properties realization of not only more subtle, more economic and more aesthetic structures but in particular more durable and reliable structures which is of the most importance from a global point of view. The development of HPC falls at the beginning of the 70th of the last century, when the application of new types of plasticizers enabled to reduce water-cement ratio below 0.35 and thus to achieve concrete of higher strength [1]. High strength concrete is used in structures in order to increase load bearing capacity in compression zones or to improve durability and reliability of the structure due to denser HPC microstructure.

The concept of subtle frame from HPC for energy efficient building includes the conceptual design of the load-bearing structure based on theoretical analysis and optimization, analysis of technical parameters and experimental verification of materials, components and their connections, including the assessment in the terms of fire safety and acoustics. The technical solution is focused on the use of high performance concrete (HPC) with environmentally optimized composition that allows the application of subtle load-bearing elements. Mechanical characteristics of HPC allow the subtle elements design with savings between 50 and 70% of concrete [2]. Subtle skeleton structure based on HPC has the potential for use in construction of buildings meeting the requirements of the next-generation complex quality criteria for sustainable construction.

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One of the most promising applications is the combination of subtle HPC frame with envelope based on timber frame and high effective insulation. This combination can be a conceptual way towards construction of multi-storey buildings with major use of renewable materials, keeping mechanical and fire safety requirements on required level.

Light frame from high performance concrete

A new optimized subtle precast construction system based on high performance silicate composites is particularly aimed for building construction in passive or zero-energy standard. The specially developed high performance concrete will be used for the superstructure. That allows the subtle elements application in optimized load-bearing building's skeleton.

The HPC frame structure is intended for construction of 2 to 6 storey buildings for residential and some public buildings (health and social care, education, temporary accommodation, administration). With regards to efforts for broader application of renewable natural materials in construction - especially wood - even for multi-storey buildings, it is assumed to use subtle HPC frame structure as the load-bearing frame for timber construction. This combination can promote the use of renewable construction materials for large-scale objects. In comparison to whole timber structures it can take advantage of silicate based floor structures in terms of acoustics (especially sound insulation), fire safety, thermal energy storage and overall spatial stiffness.

The HPC frame structure is an open modular construction system made up of subtle prefabricated columns in combination with precast concrete girders and panels of floor structure. Proposed alternative cross section of subtle column is apparent from Fig. 1. It is possible to integrate subtle structural elements into a building envelope of energy efficient buildings with significant reduction of envelope structure and avoiding risk of thermal bridges.

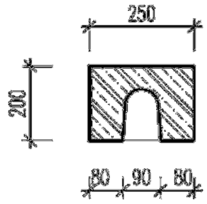

Fig. 1 Cross section of subtle HPC column

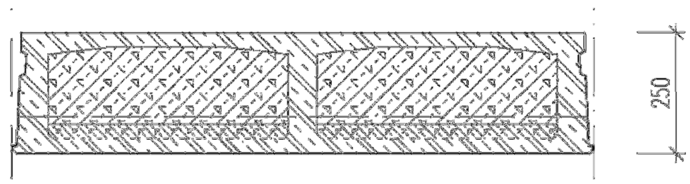

Fig. 2 Floor panel from HPC and lightening fillers

Prefabricated floor structure is ribbed or waffle structure with optional prestressing in one or both directions. Ribs are designed from high performance concrete. The panel is lightened by lightening elements (Fig. 2) alternatively from different materials - either based on natural or recycled materials (wood shavings concrete, stered concrete, polystyrene concrete). Lightening elements are designed with density of around 500 kg/m^3 in order to fulfill acoustics requirements together with upper HPC deck with thickness only 30 mm.

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Ceiling panels are considered according to preliminary optimization studies in two alternatives of reinforcement: i) regular steel rods for panels with a span of up to 6 m, ii) tendons for panels with a span of over 6 meters in the case of large live load.

First experimental elements were made with lightening elements from liapor concrete and were reinforced by two longitudinal reinforcement in the rib profiles R20. The dimensions of floor panel were B/h/L = 1.2/0.27/6.0 m. The cross-section of first elements is in figure Fig. 2. Overall three testing elements were produced and tested by four-point bending test. The average strength achieved at serviceability limit state was 112.2 kN, which means area load of 52.5 kN/m^2. The design load was 6 - 8 kN/m^2, therefore all samples fulfilled standards requirements in terms of ultimate and serviceability limit states. Currently the production of pre-stressed floor panels and girders is in the process.

Fig. 3 Manufacturing and testing of first prototype of floor panel from HPC with lightening shell elements

The crucial condition for utilization of subtle HPC frame is the design of the connection system between columns and girders. Therefore, the experimental verification of cohesion of HPC columns with Peikko corbels was proposed. Three various sets of experimental elements were produced: i) columns from ordinary Portland cement concrete OPC C35/45 with dimensions 280 x 280 mm, ii) subtle columns from HPFC70/85 and iii) subtle columns from fine grained concrete with compressive strength of 140 MPa. So far, the samples from OPC have been tested.

Significant advantages of subtle elements are material and energy savings during production, transport, manipulation and construction on building site. Optimized subtle HPC skeleton presents effective alternative to wooden framework by providing possibility to build higher buildings, to get higher spatial stiffness and better fire safety and acoustic properties of concrete floor structures while allowing the other structures to be based on wood.

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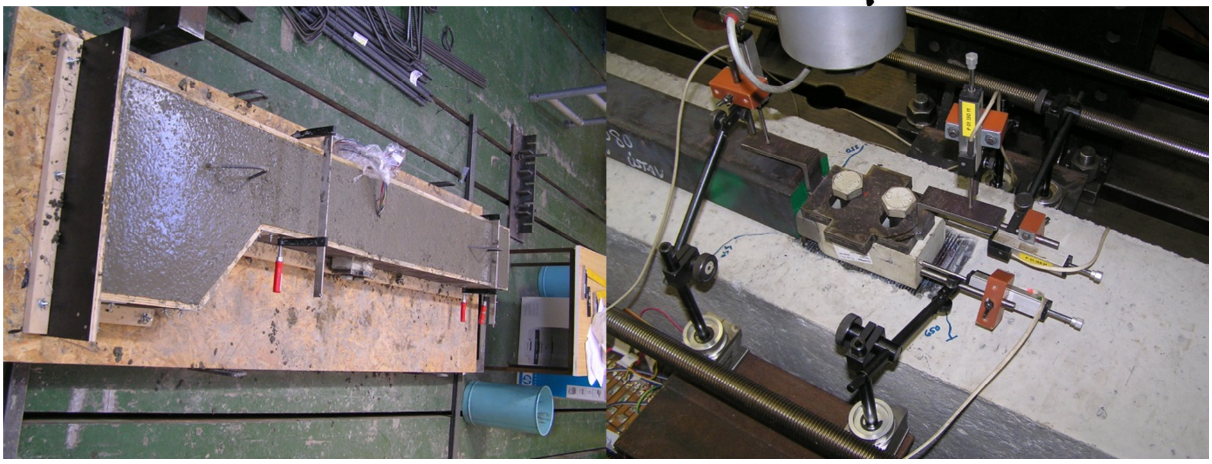

Fig. 4 Manufacturing of experimental subtle specimen (column) for verification of cohesion of HPC and corbel of Peikko system; on the right is reference specimen from ordinary concrete at testing

LCA of concrete frame structures alternatives

A set of environmental information data on concrete components and related processes has been collected and determined within the research performed at the CIDEAS centre of the Czech Technical University in Prague. These data are based on regionally available materials and are based on source data provided by companies producing and/or selling their products mainly on the Czech market. The data have been stored and organized in ICF concrete LCA$^{\text{Tool 3.0 CZ}}$ [3].

A simple six-storey building with a ground plan of approx. 10 x 20 m was chosen for life cycle analysis (LCA) study covering environmental assessment and comparison of three selected concrete frame structure alternatives (Fig. 5). The house is designed with a very universal layout enabling design of many feasible structural and material alternatives. The same ground plan can be used for residential as well as for office building. The layout is intentionally not rectangular because the construction system has to allow connection between column and girder not only under 90°.

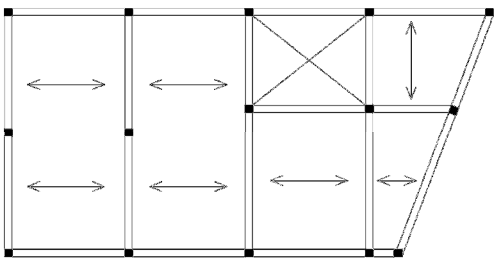

Fig. 5 Six-storey building – ground plan

Description of concrete frame structures alternatives

The complex (LCA) was performed for three various RC frame structures that were designed for afore mentioned building. This analysis focuses primarily on load-bearing structures and does not cover building envelope, partitions and surface finishes. The analysis covers

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transport of the raw material to the concrete plant, concrete production, transport to the building site, pumping of fresh concrete, formwork, demolition and deposition of the concrete at the end of the structures lifespan. The RC frame structure's alternatives are as follows:

- **V1** reference monolithic RC frame structure from concrete C30/37 with columns dimensions of 350 x 350 mm, girders 350 x 500 mm, monolithic floor slab with thickness of 230 mm, with main reinforcement in on direction.
- **V2** precast RC frame structure from concrete C30/37 with columns dimensions of 300 x 300 mm, precast girders 300 x 450 mm and hollow core panels with thickness of 250 mm.
- **V3** subtle HPC frame structure from concrete HPFC70/85 with columns as shown in Fig. 1, girders dimensions of 200 x 400 mm and floor structure panels as described in chapter above, Fig. 2. Floor panels are lightened by lightening elements from wood shavings concrete. HPC is reinforced by dispersed steel microfibers in amount of 60 kg per cubic meter of fresh concrete (1% vol.).

Cross-section of columns and floor structures for all afore mentioned alternatives V1- V3 are shown in Fig. 6.

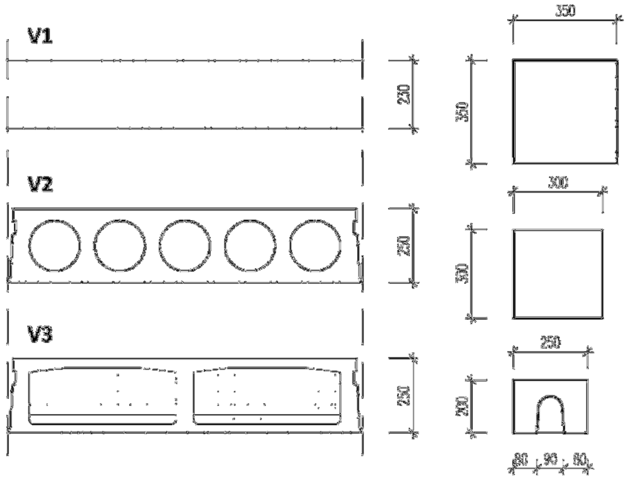

Fig. 6 Floor structures and columns alternatives – cross section (V1 – monolithic RC frame with full RC slab, V2 – precast RC frame with hollow core RC slab, V3 – subtle precast HPC frame with panels lightened by lightening elements from wood shavings concrete)

Inventory of input data: In the following analysis the expected life span of frame structures was considered for all alternatives equally 100 years. Construction life phase covers: amount of used concrete with respect to production technology (precast or monolithic), amount of individual components needed for concrete production, amount of the reinforcement divided according to a type of reinforcement, amount of used formwork or supporting structures if relevant and related transport to construction site. End of life phase calculates with the amount of waste from demolition, amount of demountable components that can be reused and again related transport.Wood shavings are considered as waste product, therefore only energy for transport of wood shaving to concrete plant is considered in analysis.

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Aggregated LCA results: Aggregated impact data for specific life cycle phases construction are presented in Tables 1. It is evident that environmental impacts in the construction phase are significantly higher in comparison with end of life phase.

Table 1 Aggregated impact data of construction life phase

CONSTRUCTION				
Aggregated data of assessment variants	unit	V1 TYPE_1_M C30/37	V2 TYPE_2_P C30/37	V3 TYP_3_P HPFC70/85
consumption of primary raw materials	kg	1 085 025	752 366	577 550
water consumption	m^3	479.6	345.0	460.0
primary energy consumption[1)]	MJ	1 570 631	1 525 161	1 589 748
global warming potential | GWP	kg	190 368	164 248	176 740
acidification potential | AP	g	842 800	741 056	715 606
photochemical ozone creation potential | POCP	g	34 179	28 487	26 856

Note:
[1)] non-renewable primary energy

The higher water consumption of V3 (subtle HPC frame) in comparison to V2 (precast RC frame) in construction life phase (Tab. 1) is connected with production of lightening elements from wood shavings concrete. Wood shavings have high water absorption, therefore the needed water for cement hydration has to be increased by the amount of water that will be absorbed by wood shavings and evaporated later during the drying process of lightening elements. In all other criteria there shows V3 best results from all assessed alternatives.

Figure 7 shows the influence of individual components such as cement, aggregate, water, admixtures etc. on primary energy consumption. It is apparent that main environmental impact is due to cement and steel reinforcement. Transport, construction process, aggregates and admixtures cause minor effect.

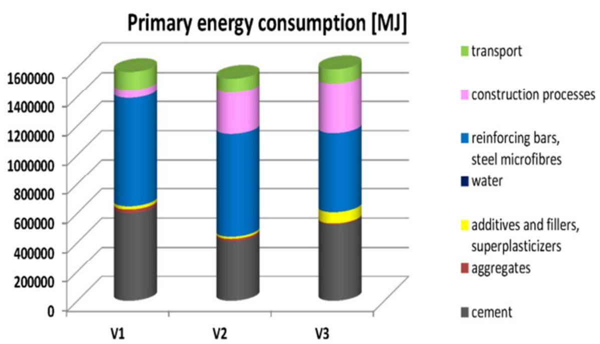

Fig. 7 Aggregated data – primary energy consumption per unit area of all alternatives in MJ

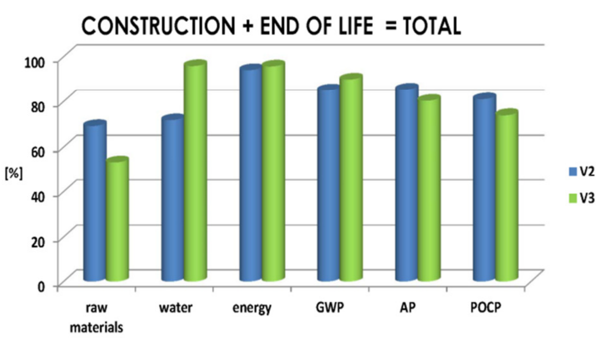

Fig. 8 Aggregated data – primary energy consumption per unit area of all alternatives in MJ. (GWP – global warming potential, AP – acidification potential, POCP – photochemical ozone creation potential)

Results and discussion

Figure 8 presents the comparison of assessed alternatives. 100% is represented by V1 (monolithic RC frame structure from C30/37). V1 alternative has the highest environmental impact in all assessed criteria. More than 30% of raw material consumption can be saved by utilizing V2 alternative (precast

RC frame with hollow core precast slabs) and further 17% by designing structure as subtle HPC frame (V3). V3 alternative shows the highest environmental savings in almost all assessed criteria (with exception of water consumption due to high water absorption of lightening elements from wood shavings concrete). Savings range from 4 to 47% when compared with V1, and from 5 to 16% in comparison with V2. The values embodied energy and $CO_{2,equiv.}$ emissions of V3 variant are comparable with values of V2.

Conclusions

Three alternatives of RC frame structures have been analysed and compared. The results of analysis proved expectation that subtle HPC frame structure is the most environmental friendly alternative from all assessed alternatives. The results show that the high quality of mechanical and environmental performance of new silicate composites creates the potential for wider application of High Performance Concrete in building construction in the future. The further advantage of subtle HPC frame can appear in areas with regulated size of built-up area (e.g in dense inhabited town areas). With higher demands on thermal insulation parameters of building envelopes increases also their thickness. The possible integration of subtle columns in building envelope can thus save valued inner space.

LCA methodology has been well known for many years. The effective application and quality of results are dependent on the availability of relevant input data obtained using a detailed inventory analysis, based on specific regional data sources. The study has showed that using a detailed LCA analysis for different alternatives of concrete structures with the approximately same performance quality, the resulting environmental impacts can be very different. This is caused not only by a different amount of used concrete, but also by different composition of the concrete mix, differences in transport and production processes. The evaluation of the real level of environmental impacts of concrete structures thus should be based on a detailed LCA analysis using locally relevant data sets.

Acknowledgement

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Basic physical properties of lime from the shells of Japanese scallops and its environmental performance as an interior finishing material

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Abstract: *Interior finishing materials play a major role in improving comfort and air quality indoors. Thus building materials and natural materials that have adjustment of humidity and deodorization function have come to attract a lot of attention.*

In this research, basic environmental performances of lime of scallop shells as interior materials are evaluated. Now Japanese scallop shells are disposed, however they can be used as substitutes for limestone because scallop shell and limestone are composed of same calcium carbonate and they also absorb CO2 in the air. Moreover, scallop shells absorb carbon in the sea in the process of their growth.

The experiment proved lime of scallop lime is better than common vinyl wall paper in moisture buffering effect and deodorization. Furthermore, this research has shown that lime of scallop shells plasters has a property of water repelling unlike general lime of limestone plasters.

Keywords: shells of Japanese scallops, basic physical, environmental performance, Life Cycle Assessment

1 Introduction

Interior finishing materials play a major role in improving comfort and air quality indoors. Vinyl fabric is often used as an interior finishing material in many houses but it does not help to improve the environment indoors, and some interior finishing materials may emit toxic substances because of the adhesives used to affix them. Building materials that control humidity and absorb odors have garnered attention. Moreover, highly safe and highly functional natural materials are being reconsidered. This study has focused on lime made by firing Japanese scallop shells, which are treated as industrial waste, to yield a natural material. A small quantity of scallop shells is used as a chicken feed or to improve land (as a filter material for underdrains). However, the use of shells to improve land has come about as the result of a subsidy, so if that subsidy were to end then the shells would no longer be used for that purpose. Ways to use scallop shells need to be identified. Therefore, this study has examined the basic physical properties of lime from the shells of Japanese scallops and it has evaluated their environmental performance as an interior finishing material. Moreover, this study assessed the life cycle of lime from Japanese scallop shells since these scallops absorb carbon from the sea as they grow. This study has examined the usefulness of lime from scallop shells.

2 What is lime from scallop shells?

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A principal component of modern plaster is limestone. Limestone is fired, ground into powder, and then water is added for the lime plaster to be used. In contrast, lime from scallop shells comes from shells that are discarded when the scallops are eaten. Lime from scallop shells is produced the same way was lime from limestone. However, lime from scallop shells is environmentally friendly in the sense that waste is being used. Furthermore, scallop shells absorb carbon in the sea as the scallop grows. Therefore, the shells can fix carbon. This action is similar to carbon storage by wood.

3 Basic physical properties of lime from scallop shells

3.1 Elemental analysis of lime and lime from scallop shells

3.1.1 Overview of testing

Energy dispersive X-ray spectrometry was used to conduct an elemental analysis in order to compare lime from scallop shells with lime from limestone.

3.1.2 Testing results

Testing revealed that lime from scallop shells and lime from limestone had the same constituents and that lime from scallop shells could substitute for lime from limestone.

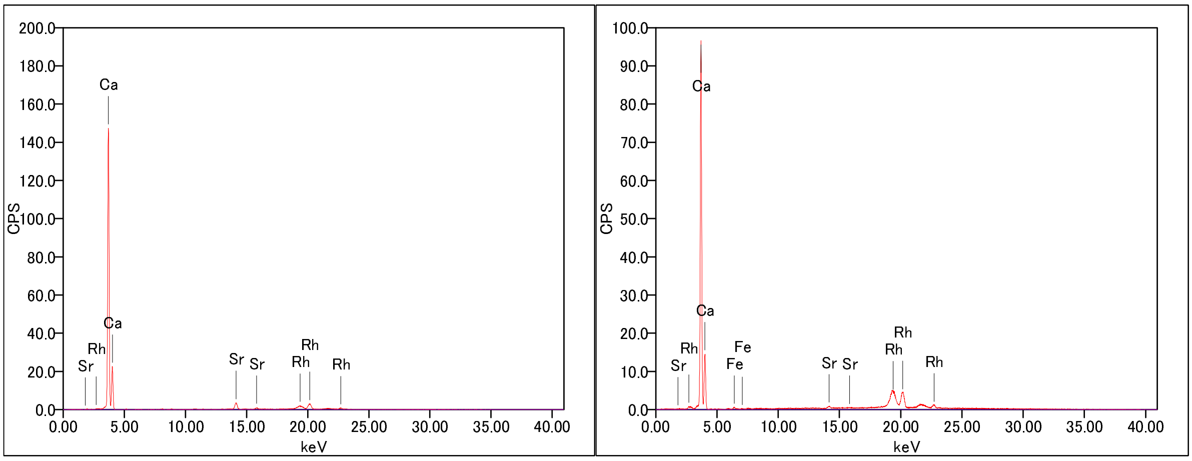

Fig. 1 Results of elemental analysis
(Left: lime from scallop shells, Right: lime from limestone)

3.2 Study and analysis of heat transfer

CO_2 emissions during the manufacture of lime from scallop shells and lime from limestone were examined. Companies manufacturing lime from scallop shells were surveyed. The emission factor for lime from limestone was updated to 2013 and calculated based on a previous survey by this Laboratory.

Results indicated that CO_2 emissions during manufacture vary greatly depending on the company. Producing lime from scallop shells involves a large amount of CO_2 emissions due to small-scale production. Calcination and decarbonization account for most of the CO_2 emissions during the manufacture of lime from scallop shells and lime from limestone. Lime from scallop shells and lime from limestone have the same amount of decarbonization, i.e. 44%. However, the decarbonized portion accounted for 75% of Lime B from limestone.

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Calcination can be reduced by increasing efficiency, so the decarbonized portion will be an issue in the future.

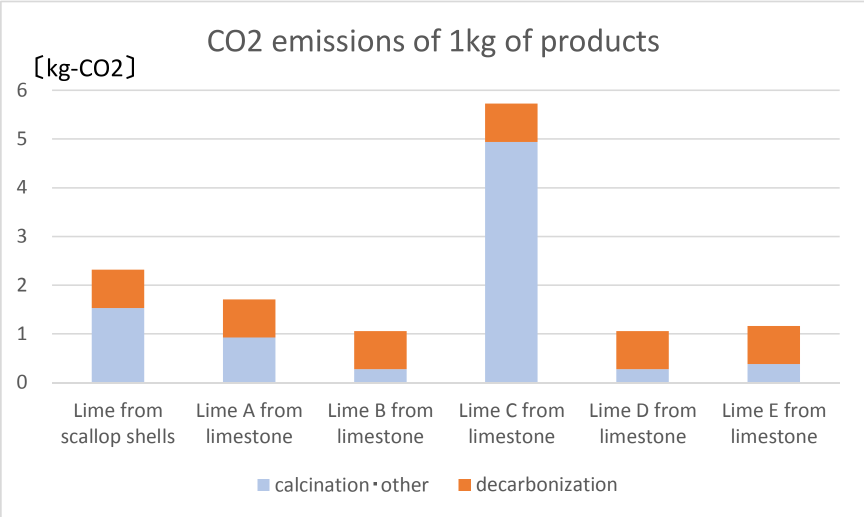

Fig.2 Carbon dioxide emission by 1 kg of product

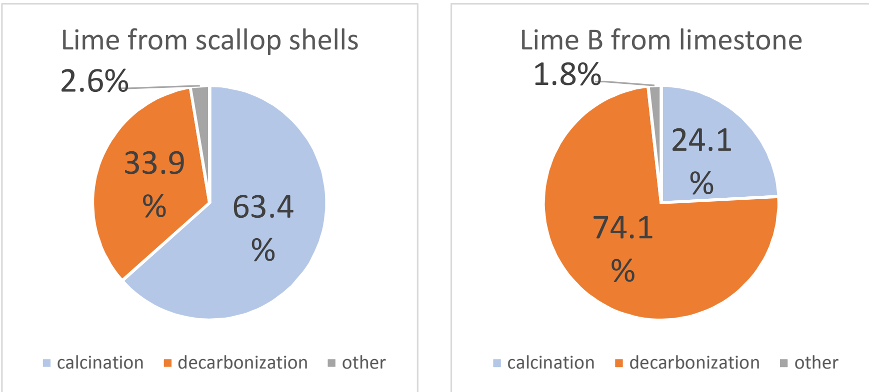

Fig.3 Rate of CO2 emission
(Left: lime from scallop shells, Right: lime from limestone)

4 Assessment of the life cycle of lime from scallop shells

Reducing decarbonization is important for the reasons cited above. However, lime from scallop shells and lime from limestone re-adsorb carbon after they are plastered on a wall. Furthermore, scallop shells absorb carbon during scallop growth. For this reason, lime from scallop shells is friendlier to the global environment than lime from limestone.

5 Environmental performance of interior finishing materials made of lime from scallop shells and lime from limestone

5.1 Overview of specimens

Specimens were produced using a traditional plastering technique. A has a thin coating of plaster, B has a thick coating of plaster, and C has a polished finish. However, a polished finish cannot be produced with lime from limestone, so polishing was only partial. A polished finish was readily achieved with lime from scallop shells.

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The plaster finish contained aggregate. A polished finish not containing aggregate was also included. Such a finish cannot be produced with lime from limestone but it can be produced with lime from scallop shells. In addition, a thin coating and a thick coating of plaster were prepared.

		layer ①				layer ②				layer ③			
No.	name	material	aggregate	ratio	thickness	material	aggregate	ratio	thickness	material	aggregate	ratio	thickness
1	Lime A from scallop shells	scallop shells	silica sand	1:1	2mm	scallop shells	–			scallop shells	–		
2	Lime A from limestone	limestone				limestone	–			limestone	–		
3	Lime B from scallop shells	scallop shells				scallop shells	silica sand	1:1	5mm	scallop shells	–		
4	Lime B from limestone	limestone				limestone				limestone	–		
5	Lime C from scallop shells	scallop shells				scallop shells				scallop shells	silica sand	–	3mm
6	Lime C from limestone	limestone				limestone				limestone			
7	wallpaper (vinyl)	–				–				–			
8	Tile	–				–				–			

Table 1 Specimens

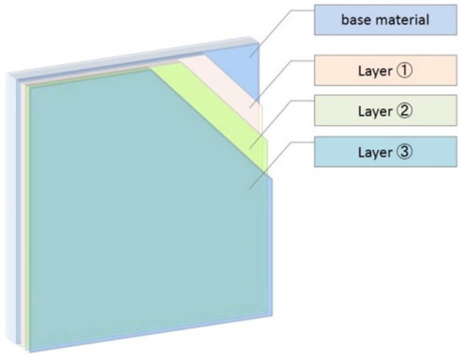

Fig. 4 Specimen

5.2 Testing humidity control

5.2.1 Test summary

This test was based on an intermediate moisture level as indicated in Japanese Industrial Standards (JIS) A 1470-1, "Determination of water vapor adsorption properties for building materials—Part1: Response to humidity variation." A specimen in a steady state was subjected to moisture absorption (23ºC, 75%, 12 hours) and then moisture desorption (23ºC, 50%, 12 hours). Tested specimens were Lime B from scallop shells, Lime B from limestone, and vinyl wallpaper for comparison.

5.2.1 Test result

Results are shown in a Fig. 5. Lime from limestone had more moisture absorption than lime from scallop shells, but the difference was slight. Results revealed that lime from scallop shells and lime from limestone had better moisture absorption than wallpaper.

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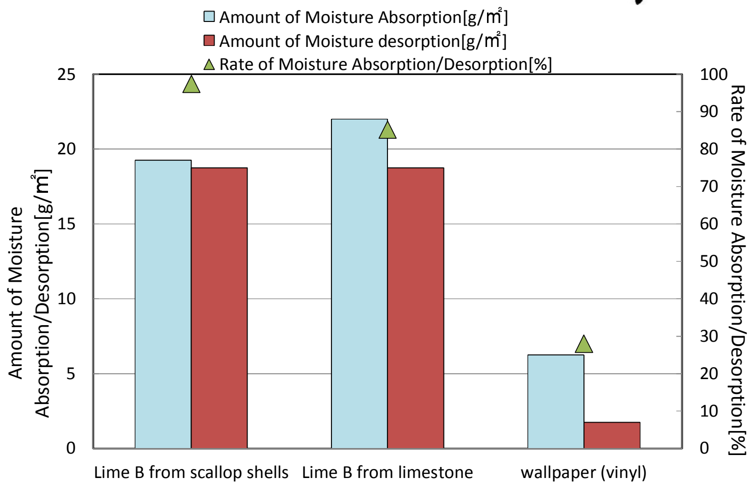

Fig. 5 Comparison of performance in terms of moisture absorption/desorption

5.3 Testing ammonia absorption

5.3.1 Test summary

This test was based on JIS A 1901, "Determination of the emission of volatile organic compounds and aldehydes for building products―Small chamber method." Specimens 10 cm square were placed in a 20-L sampling bag, and 20 L of air containing aldehydes at about three time the concentration specified by that Ministry of Health, Labor, and Welfare (MHLW) was injected. The ammonia concentration was measured after 1, 3, and 24 hours. The sample air was analyzed using high-performance liquid chromatography to determine changes in the amount of ammonia absorbed. Afterwards, specimens were placed in a new bag filled with fresh air and then placed in a chamber at about 45℃. The ammonia concentration in air was sampled and the amount of ammonia emitted by each sample was determined after 1 and 3 hours.

5.3.1 Test results

The plaster finish absorbed more ammonia than wallpaper. Lime from limestone absorbed ammonia faster, but eventually lime from limestone and lime from scallop shells absorbed the almost same quantity. The polished finish did not absorb more ammonia than the plaster finish. However, the polished finish absorbed more ammonia than wallpaper or tile.

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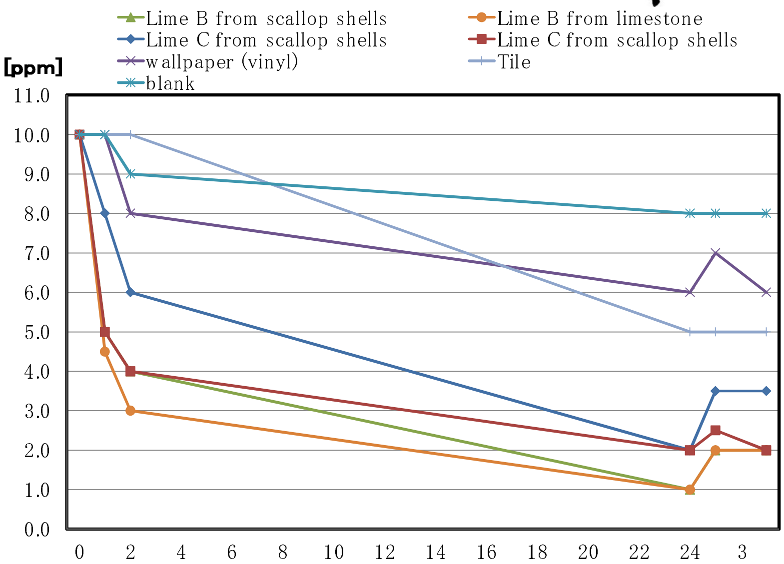


Fig. 6 Changes in the concentration of ammonia

5.4 Testing wettability

5.4.1 Test summary

Wettability was tested in order to evaluate surface water repellence. Water drops were dropped on the center of a specimen from a height of 1 cm, and the water drops were observed for 5 minutes.

5.4.2 Test result

The plaster finish immediately absorbed moisture. However, a polished finish of lime from scallop shells did not absorb moisture.

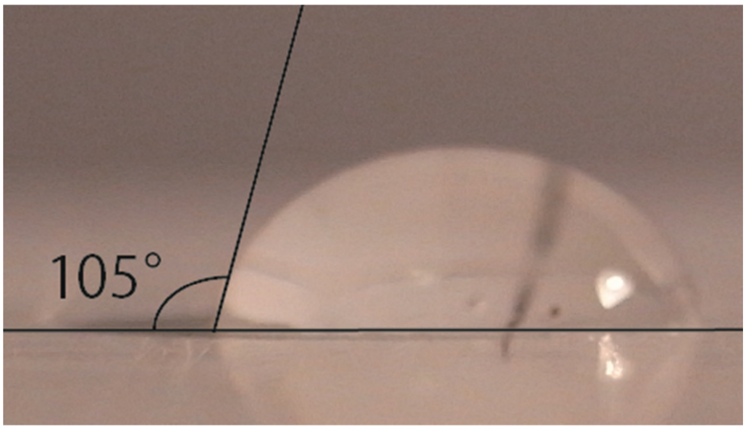


Fig. 7 Polished finish of lime from scallop shells

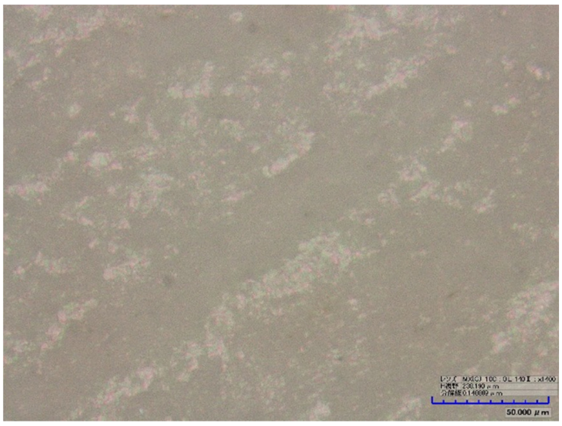
5.5 Examination of surface architecture under a microscope

5.5.1 Examination summary

The surface architecture of lime from scallop shells and lime from limestone was compared using a 1,400-power microscope and 3D images were created. In addition, differences in height were examined.

5.5.2 Examination results

Results revealed large differences in height and large holes in lime from limestone but small differences in height and small holes in lime from scallop shells.



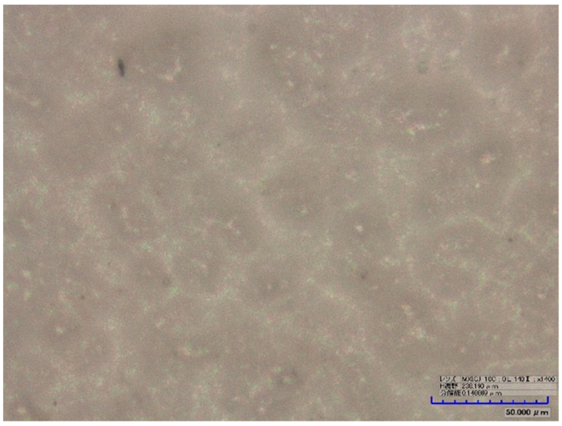
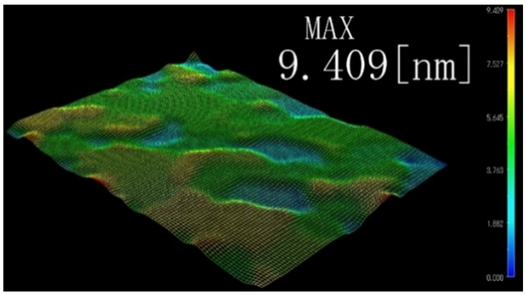


Fig.8 Examination of surface architecture with a 1,400-power microscope
(Left: lime from scallop shells, Right: lime from limestone)



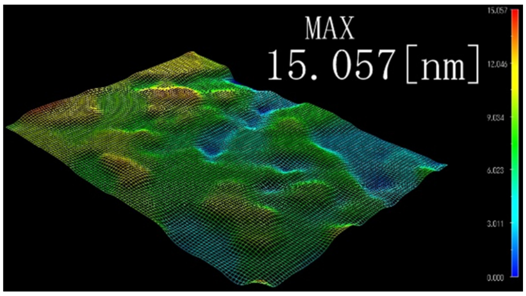


Fig.9 3D image
(Left: lime from scallop shells, Right: lime from limestone)

5.6 Examination of the cross sectional structure under an electron microscope

5.6.1 Examination summary

The specimen was cut and its section was observed with a 1,500-power scanning electron microscope.

5.5.1 Examination results

The section of lime from scallop shells had a high density, which is why it repels water. In contrast, the section of lime from limestone had a low density, which is why it does not repel water.

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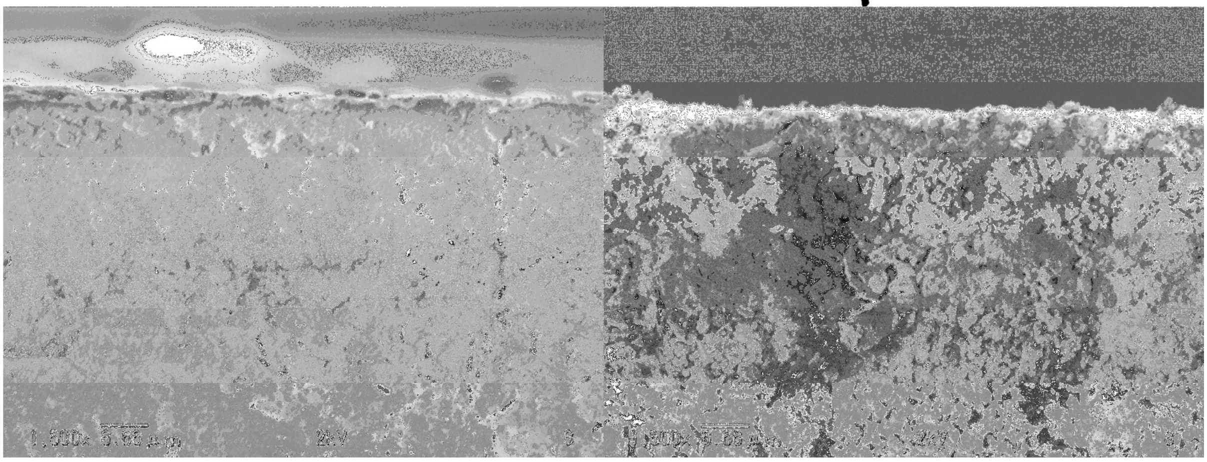

Fig. 10 Section
(Left: lime from scallop shells, Right: lime from limestone)

6 Summary

This study examined the basic physical properties of lime from scallop shells and this study evaluated its environmental performance. Results revealed that plaster performs better than wallpaper. Furthermore, results revealed that lime from scallop shells can substitute for lime from limestone. This will facilitate the recycling of waste. Unlike lime from limestone, lime from scallop shells is carbon-neutral, so it limits the load on the global environment. A polished finish was only possible with lime from scallop shells, and lime from scallop shells resulted in better moisture absorption and humidity control than tile. Plans are to test other aspects of lime from scallop shells, such as its durability, in the future and to explore the potential use of lime from scallop shells as a building material.

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Session 143:

Why isn't efficient urban design made general?

Chairperson:

González, María Jesús

ASA President (Association of Sustainable Architecture) from 2010 to 2013. Member of the Scientific Committee of the contest POWERING TRANSFORMATION

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Assessment of human intervention on social housing design considering impacts on thermal performance at residential neighborhood

Speakers:
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Abstract: *Thermal normative on building envelope has been improved since last decade in Chile. However spatial arrangements such as sun orientation and wind are not good enough in the design of social housing neighbourhood. Post-occupancy behavior has had a response against such design through physical changes on the original layout. The objective of the paper is to assess human interventions on social housing design to know the impacts on thermal performance at neighborhood scale. The question is whether those changes lead to improve or to make the habitat conditions worse.*

Methodology consists of a comparison about thermal performance of the original housing plan and rehabilited housing plan made by residents in two blocks comprise by forty houses. Local campaign was carried out measuring indoor and outdoor temperature during summer and autumn for three months. Results showed a decrease in daylight and an increase in temperature of 2°C on housing after changes made by residents affecting the original thermal performance.

Keywords, Post-occupancy rehabilitation, thermal performance, social housing design, energy regulation

Introduction

Sustainability indicators and rating tools for neighborhood rehabilitation is a matter linked to national commitment and the users as well. So the paper firstly explore legal and institutional energy framework related to buildings and urban system and secondly explore users point of view. A brief literature review will be discussed then a developed research will be exposed to show importance of post-occupant behavior to adapt to changes for comfort purposes. Finally results show moderate temperature and reduction of luminance values at indoor house with economic and social consequences of post-occupancy rehabilitation.

Energy efficiency on building is a matter of national policy in Chile [1]. The National Energy Agenda has already addressed seven points as follow: (i) State role, (ii) price reduction by competition, efficiency and market diversification, (iii) development of their own national energy resources ERNC, (iv) system connectivity across national land, (v) energy efficiency to manage consumption, (vi) infrastructure investment, and (vii) citizen participation and planning of territory [2]. The National Law of Urbanism and Building has an Ordinance with specific mandates (Art 4.1.10) for thermal compulsory measures based mainly on

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architectural envelope in new housing [3]. Thermal regulations have been implemented since the 2000. At the beginning concepts such as thermal transmittance and resistance dealt with roof alone but in 2007 other construction systems as wall and floor were included as well. Comfort temperature indoor house was estimated according to days-degree concepts to achieve 15°C plus internal gains from equipment, people, and light to reach the 18°C. At present the Technical Construction Organism (DITEC) of the Ministry of Housing and Urbanism is studying how to improve those regulations including other parameters such as air infiltration, amplitude of outside temperature, etc. So energy efficiency is a national concern issue from the state as a way for sustainable cities. National state is already implemented energy code for domestic artifacts and it is studying compulsory building code for housing according to international indicators such as LEED, BREEAM, GBTool, etc. for the 2015 year.

However scale of neighbourhood and surrounding is not addressed yet as a national concern for sustainability indicators from spatial urban design perspective. Although there are centuries of previous experience from Vitrubio (IV BC) with his classical principles The Ten Books of Architecture passing through the Bioclimatic Architecture from Olgyay in the sixties, more over Higueras with Urbanismo Bioclimático in the eighties and the current Sustainable Architecture [4], [5], [6], [7].

There is also a National program called “I Love my neighbourhood” lead by the Ministry of Housing and Urbanism. Its objective is to improve quality of lives and public spaces by investing on infrastructure, green areas, pedestrian mobility, recover ecosystems, garbage, social services, and security pathways, to reinforce social networks to prevent vulnerability. However this program does not tackle energy issues nor sustainability related to urban design as mentioned above [8].

On the other hand The Chilean Constructions Chambers has implemented many activities as courses, technical documents, seminars, training courses and so on about energy efficiency and sustainable building since two decades ago [9]. At the scale of the neighbourhood construction sector has participated in a program called Protection of Family Heritage launched by the Minister of Housing and Urbanism. The program consists on the installation of thermal solar panel on the new social housing roofs, with subsidies from the state [10]. Rehabilitation of old buildings which considers energy efficiency is also an issue but it deal mainly with thermal insulation for the architectural envelope. Active measures tend to promote the use of solar panels for thermal or photovoltaic purposes. All previous initiatives have demonstrated that they focus mainly on both building as a single element rather than neighbourhood and the system of construction, whether material or solar devices, for new developments.

All activities are conducted by professionals and a question arisen is how residents try to modify initial housing plan to improve comfort conditions for living?

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Scarce is an implicit concepts linked to the social housing at neighbourhood scale. Although that urban design should deliver the best layout for maximizing natural resources and environmental quality of live. When it does not happen then occupants change original plan to reach better indoor-outdoor comfort conditions. However this post-occupancy rehabilitation tends to worsen their habitat because of lack of technical knowledge about bioclimatic design for architecture or urbanism.

The objective of the paper is to explore human interventions on social housing design considering the impacts on thermal performance at residential neighbourhood. Post-occupancy behaviour tries to adapt to the original architectural design living within the house. Occupants every day learn quite well about limitations and strength of its plan whether indoor or outdoor spaces. Coming times they tend to change because they feel discomfort on those places. It is interesting to know about similar modifications on social housing layout at neighbourhood scale in order to identify variables for rating tools for sustainability indicators.

According to Baird [11], the inclusion of user performance criteria in buildings sustainability rating tools (BSRTs) is a key factor for making progress to sustainable buildings. He argues that technical factors belonging to the current set of buildings rating tools such LEED, CASBEE, BREEAM, GBTool, Green Star Australia, etc., applied to new buildings can be degraded by unexpected behaviour by occupances. Some existing buildings perform poorly from user point of view so it is necessary an occupant satisfaction survey which it is recently included in the Australian NABERS protocol.

Research methodology

To study human interventions on social housing design and old enough project was necessary to choose to see modifications already done by its occupants. A housing project built on the 1970s, located in a southern district of Santiago city called El Bosque, was selected as case study. It has a density of 133 hab/ha which means a quite high average compares to the metropolitan average. A block in which attached houses are located was chosen because suitability for comparison. On the one hand shows urban facades with different orientation but identical original house plan and on the other it offers a myriad of human interventions. Figure1

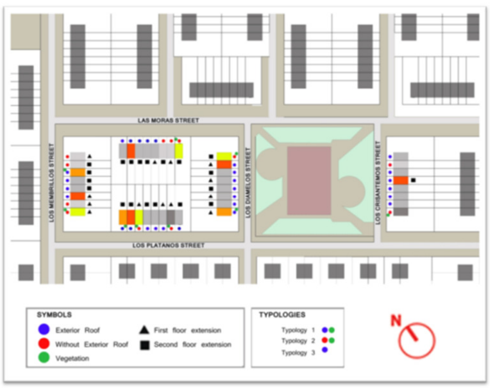

Figure 1. Plan of the social housing project located in El Bosque district, Santiago city.

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Three typologies of human interventions on the original social house design are shown in figure 2. They are representative of typical changes observed in the four attached buildings situated on the block as follow: (i) facades added roof garage and vegetation, (ii) facades with deciduous vegetation, and (iii) facade added roof garage alone. A comparison according to cardinal orientation of the main facade was made for each typology: house in front of pathway Los Membrillos (NW), house in front of pathway Las Moras (NE), house in front of pathway Los Diamelos (SE), and house in front of pathway Los Platanos (SE) A typical house has 45.5 m^2 and a site has 73.1m^2 with two floors. First floor delivers living-room, dining-room and a kitchen while the second floor delivers 2 rooms and a bathroom.

i) facades added roof garage and vegetation, (ii) facade with deciduous vegetation (iii) facades added roof garage alone

Figure 2 Typologies of human interventions observed on social housing project, El Bosque district.

Method for analysing indoor and outdoor thermal performance was carried out by monitories and simulation. The former consist on a campaign of measurements of temperature (°C), relative humidity (%) and luminance (luxs) for fourteen days between February and May in a clear sky. The latter consist of energy simulation using ECOTECT ® and RADIANCE ® tools to apply to a cadastral plan and a 3D model created for that purposes. Figure 3 shows the model plan pointing out shadow on winter solstice, the 21th June. According to on-site inspection most of human interventions try to add an outdoor space so it defines new architectural zones: A, B, and C as figure 4 shows.

El Bosque district belong to Santiago metropolitan city which is located in a basin crossed by two rivers and a Mediterranean climate. It is characterised by a long semi-arid six months period and a concentration of rains in three months between May and August reaching almost 300 mm of falling water annually.

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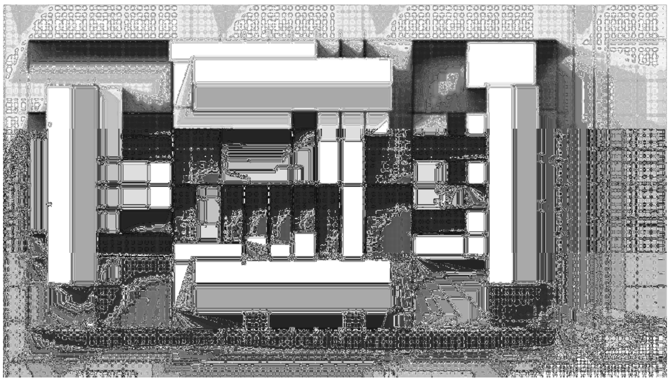

Figure 3 Model plan modelling shadows on surrounding for winter solstice (9:00hrs - 17:00hrs)

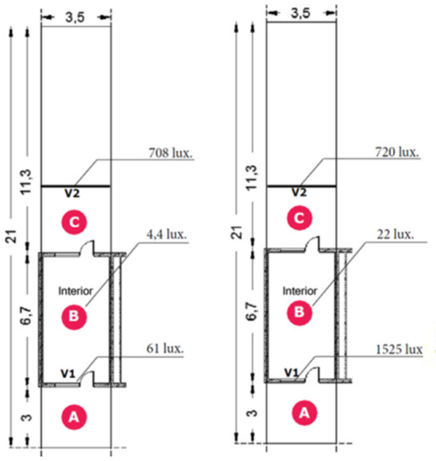

Figure 4 New architectural zones defined by post-occupancy rehabilitation (A, B, and C)

Thermal performance on social housing at neighborhood

A survey of 30% total houses from the block was analysed to compare variables affecting comfort conditions. Result of one typology is displayed here from the whole investigation as show table 1 and figure 5. Ambient temperature (°C) is higher in all zones for housing located in the North urban facades as expected. By contrast, the lowest value registered in site pointed out a house located in the South-East urban facades. It is interesting to note that zones a, b and c has different thermal performance depend on orientation of the main urban façade. Zones of housing situated in the South-East façade has a similar temperature value reaching 18 °C while those situated in the North-West facades reach 22°C. There are 4°C between maximum values in zone A corresponding to an identical space which added roof garage. Moreover it is important to highlight amplitude of 2°C between zones situated in the North-West facades. So the space closed by owners, as a mean of post-occupancy rehabilitation, has a mild effect on ambient temperature. Energy simulation on each urban facade was made to show irradiation values and hot effects directly on it when assuming no human intervention. See figure 6.

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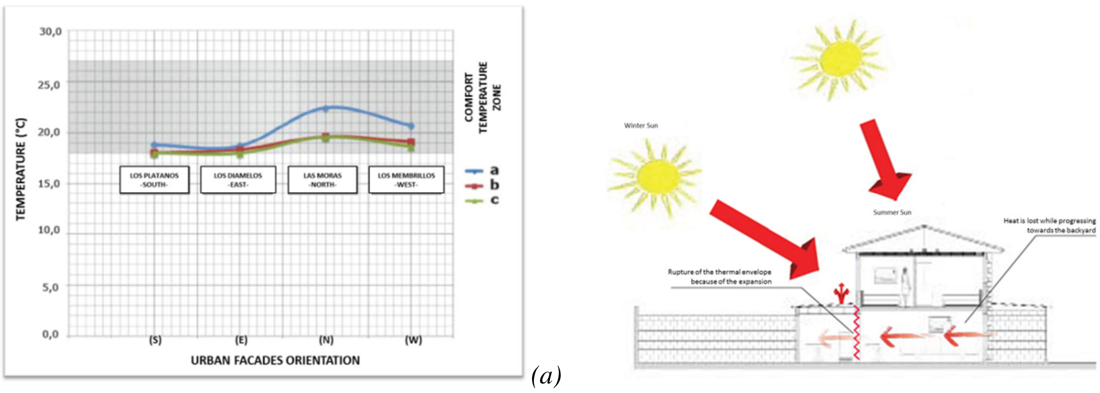
Table 1 Average of temperature and relative humidity of housing typology: facade added roof garage alone

Average Temperatures (°C)				
	Pasaje	a	b	c
SE	Los Platanos	18,83	18,05	17,98
NE	Los Diamelos	18,73	18,36	17,95
NW	Las Moras	22,46	19,64	19,59
SW	Los Membrillos	20,74	19,14	18,65

Average Relative Humidity (%)				
	Pasaje	a	b	c
SE	Los Platanos	44%	51%	50%
NE	Los Diamelos	35%	43%	34%
NW	Las Moras	33%	40%	35%
SW	Los Membrillos	30%	35%	45%



(a) (b)

Figure 5 (a) Summarise of ambient temperature (°C) measured on zones a, b, c in the same house but located in each urban façades. (b) Cross section of housing typology: facades added roof garage alone.

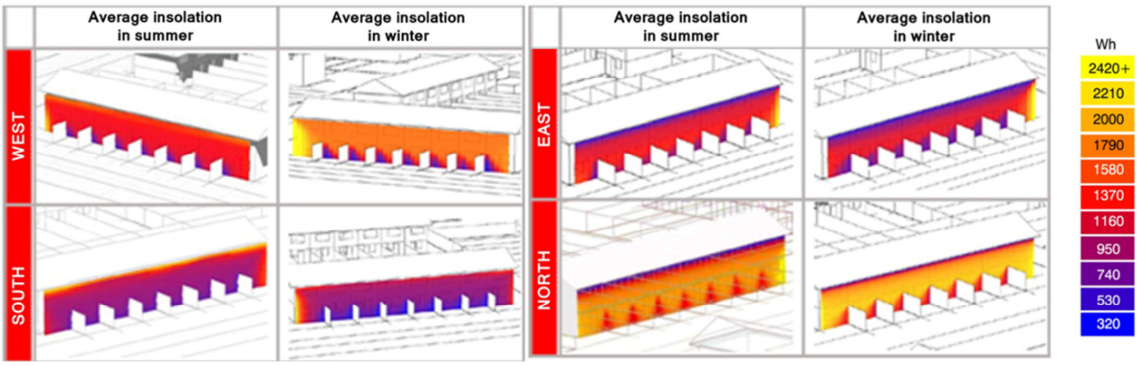


Figure 6 Simulation of irradiation value falling directly on urban facades without human intervention

Finally a scheme presented in figure 7 shows interior darkness in the modified house in which direct consequence is more energy consumption whether electricity for lighting or heating. Luminance effects on indoor original house and indoor modified house is compared by RADIANCE® simulation tool as see in figure 7. The former received more lux that the latter.

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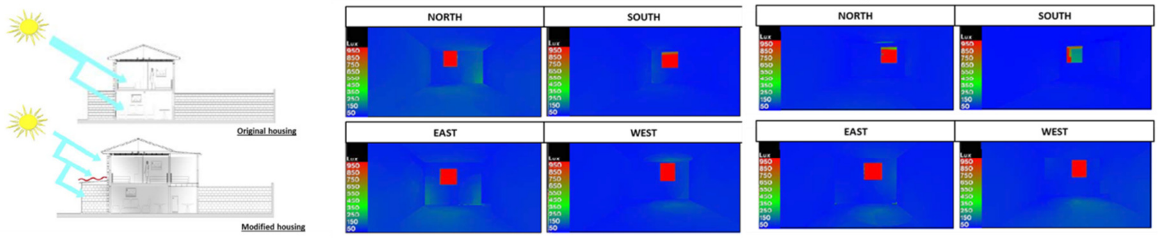

Figure 7 Simulation of luminance values comparing indoor house. (left) original design (right) modified design

Post-occupancy rehabilitation

Human interventions on social housing design have been evaluated from thermal performance perspective. Is is noted that modifications based on roof garage added on façade has different effects on temperature according to cardinal orientation. As expected North West tend to register maximum values compares to other facades. However the new space between indoor and outdoor means a transitional space which moderate temperature. In summer might be appreciated because of heat but in winter might be not desired due to decrease furthermore outdoor temperature. Sustainability indicators for rating tools should considers homeowner needs because they might change previous plan design and then modified established thermal comfort, particularly in the case of social housing. It is expected a growing trend in the future to improve living conditions what it is known as post-occupancy rehabilitation.

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A Novel Real-Time Traffic Monitoring System Based on Cellular Networks

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Abstract: *The integration and coordination of inter-city and intra-city travel is vital for proper intermodal trip planning. Highly dense cities with no available physical extensions can use Intelligent Transportation Systems (ITS) to alleviate the increasing congestion and to provide more reliable systems based on travel information availability. In Egypt, the absence of reliable trip schedules and traffic monitoring systems hinders the development of intermodal transportation either by network planners or by the travelers themselves. This paper presents a novel idea for a real-time traffic monitoring system for intermodal travel as a cost effective and sustainable alternative. The proposed model is built on cellular networks without a secondary reference system. Data swarm clustering algorithm is used to extract real-time vehicular-based traffic data by tracking anonymous CPs carried by travelers. The model showed superior results; average GEH of 0.27±0.24 and MAPE of 95.65±3.55.*

Keywords: Cellular Phones, Traffic Monitoring, Clustering, State Estimation & Prediction

Introduction

Transportation network and systems development have not been at adequate rates to the increasing travel demands without proper improvement and maintenance. Resulting aged, inefficient, and highly congested transportation systems. Travel information for travelers, fleet operators and traffic management centers avoid travel time delay, reducing traffic congestion. In 2010 1,210,000 passenger car units travelled GCMA at peak hours. Only 23% of daily trips were by public transport. Public transport level of service in GCMA is very low, it is centralized, and most locations have no transport coverage. The total annual congestion cost in GCMA is 13-14 billion LE. (56% by passenger cars and 41% by public transport). 36% of congestion was from travel time delay, 37% by recurrent and non-recurrent congestion & excess fuel cost, 25% due to unreliability, and 2% by CO_2 emissions (1).

Intelligent Transport Systems (ITS) integrate information and communication technology with transport infrastructure, vehicles and users to allow a better utilization of transport networks. ITS enhance safe mobility for both people & freight, reducing traffic congestion, managing the transportation infrastructure more effectively and economically and reducing fuel consumption and emissions. The deployment of ITS systems is promoted widely by rapid diffusion and development of electronic devices, cellular phones and internet services. A traffic monitoring system is the backbone for successful traffic management processes and presents both real time and historical traffic data. A monitoring system collects real-time data from either road side units at fixed points as; radars, loop detectors, and video cameras … etc, or from movable stations, as probe vehicles and Global Positioning Systems (GPS) (2). The high cost of large scale monitoring systems hampers their development especially in developing countries. CPs aboard of vehicles are considered as are envisioned as a traffic sensor through the CPs' spatiotemporal updates (3).

In Egypt, some recent applications were introduced as Bey2olk, Wassalny, and Elzahma that started by covering GCMA and Alexandria. The information disseminated by the applications is built on active users' feedback of the qualitative evaluation of traffic conditions. By May 2013, Bey2olk has attracted about 0.5 million users out of the 3 million smart phone users in Egypt. Wassalny traced 2,591,456 km travelled by its users. Elzahma application, launched last October, supports tracing GPS assisted phones. Although these applications data is limited the active user interaction space and their reliability is not guaranteed nor yet validated, they have gained an increasing credibility by the travelers in Egypt.

Traffic Data from Cell Phones

LA of the CP is updated (LAU) through a sophisticated switching technique called "handoff" to ensures the call proceeds without interruption and the CP is connected when it moves from one LA to another (4; 5). Handoff occurs for a switched on CP moving from one LA to another or from one cell to another if on call at the LA/Cell border in about 1 to 2 sec (6). An additional periodic automatic LAU occurs for all CPs at a predefined duration, typically every 2 hrs (7). The trajectory of a trip carried out by a vehicle is built from LAUs of a CP aboard.

Traffic data extracted from CPs data described well the traffic pattern and were able to detect the normal variations in traffic pattern and at special events even if depending on a portion of CPs' users (17%) (8). A wide spectrum of traffic data can be computed from CP data such as; travel time (9), trip distribution tables (10), Revealed Preferences (RP), actual routing choices (11) and route guidance (12). However, most of the previous researches were built on the existence of a secondary reference system for data refinement and matching.

Conversely, Basyoni & Talaat in 2013 used Data Swarm Clustering (DSC) algorithm to extract traffic data from CP networks with no need of a secondary monitoring system. The approach was supported by the increasing worldwide penetration rates of CPs that reached about 96.57% in July 2011, of 77.76 Million subscribers in Egypt (13) to present a cost effective large scale monitoring system (14). The model extracted vehicular counts with temporal dimensions from anonymous passive CPs LAUs in an offline setting. The developed model was evaluated on the 26th of July corridor in Egypt. Results showed very comparative performances; the Geoffrey E. Haver (GEH) was 0.19 and the Mean Absolute Percentage Error (MAPE) was 97.59. However, the model was built on filtered inter-city trips of pre-defined OD pairs in an offline setting (14) which deters any real time (online) applications.

Problem Definition and Research Objectives

This paper proposes a novel online traffic monitoring system suitable for non-disciplined Egyptian traffic flow and that can support various modes of transport for multimodal intercity

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travel and the integrated intracity travel. The approach could be easily used, given a high CP penetration rate. However, the real-time approach is hindered by the following:

1. The absence of a network-wide reference monitoring system.
2. CPs are traced anonymously, their destinations are not known.
3. CPs in passive mode assumes that vehicles travel with constant speed within the LA.
4. Available flow-speed-density relationships cannot be used for non-disciplined traffic streams (travelling in lanes, unnecessary lane changing, and drivers' behaviors).
5. Simulation-based predictions require the availability of a calibrated network at the very first, and that is not available for Egypt.

The main objective of this research is to develop a robust, trip-based travel time online prediction procedure. The procedure extracts network-wide real-time traffic data; merely from CPs networks data based on adopting various Data Mining, Artificial Intelligence, and Machine Learning algorithms as a cost effective and sustainable approach. The procedure is adaptively calibrated in the offline setting. Detailed objectives of the research are as follows;

1. To develop a reliable real-time traffic data extraction procedure via CP networks by tracking anonymous CPs using Data Swarm Clustering (DSC) algorithm.
2. To develop a reliable trip-based, self-learning real-time travel time prediction procedure based using State-Space Neural Networks (SSNN).
3. To evaluate the performance of the procedure on the 26^{th} of July corridor in Egypt.

Literature Review

Real-time traffic data is estimated through traffic state estimation and prediction. A traffic state represents speed, density, or travel time over a section of the network during a time interval. Traffic predictions are classified into parametric and non-parametric methods. Parametric methods are statistical based and include; linear & Autoregressive Moving Average (ARMA) models, Nearest Neighbor models ... etc. Non–parametric methods, known for their robustness, include; Neural Networks, Regression models, and Kalman Filtering. Simulation platforms present powerful tools for traffic studies including traffic state prediction (11; 15) as PTV VISUM (11) and CORSIM (16). Adaptive calibration methods prevail over the dynamic nature of traffic to enhance the robustness of the prediction model (15).

Travel time was predicted from A-GPS CPs in real-time; traffic state was described by the average traffic speed (17). Gayah & Dixit predicted traffic speed states from vehicles' locations sent by CPs every 3 seconds with only 5% penetration rate based on a density-speed relationship. 93.8% of traffic states were correctly identified (18). Herring et al. used the pace of travel (time/distance) to develop reliable estimations and predictions given 2-5% penetration rates using statistical modeling (19). Diversely, Friedrich et al. used trajectories of anonymous CPs from LAUs and link counts from roadside detectors to develop typical hourly ODs. Long term forecast of hourly ODs was performed, using PTV VISUM software (11).

Artificial Neural Networks (ANN) are data-driven, self-adaptive, and non-linear approaches and present powerful tools for travel-time forecasting. Traffic states are predicted in NN by feeding it with traffic data from various sources as: loop detectors, GPS based vehicles'

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locations data, accident data ... etc. State-space Neural Networks (SSNN) as a generalized approach has the advantage of learning the non-linearity in congested traffic from the data and based on the SS method are more related to traffic flows (21). Prediction results and accuracies vary according to the type of data and methodology of the prediction tool (22). However, there is a robustness accuracy tradeoff. Yu et al. Cluster-based ANN model showed a root mean square percentage (RMSP) error of about 0.087 (1.29 mins) during peak and off-peak hours, (16). The predictor performance improves as the travel distance and time horizon increase. The travel-time prediction model adopted by Wu et al. relative mean error (RME) was 0.96% for a distance of 350 km and 3.91% for 45 km (22).

Research Methodology

This paper propses a traffic monitoring system built on cellular networks suitable for inter-city travel. Routes between different zones of interest are defined by the unique sequence of LAs IDs. Traffic data is extracted from the aggregated spatiotemporal data of anonymous CPs along a corridor. Each traffic state is defined by the segement of the road covered by one LA. Real-time traffic data is estimated in an online setting for CP-based uncompleted trips data (vehicles haven't reached their destinations) using modified Data Swarm Clustering (DSC). Following, future traffic states are predicted using a State Space Neural Network (SSNN). In the offline setting, traffic data is re-computed from the same CP-based data but for completed trips (reached destinations). Discrepancies between the estimated and predicted vehicular data in the online and offline setting are used adaptive calibration by using Reinforcement Learning algorithms. The procedure followed in this research is presented in Figure 1.

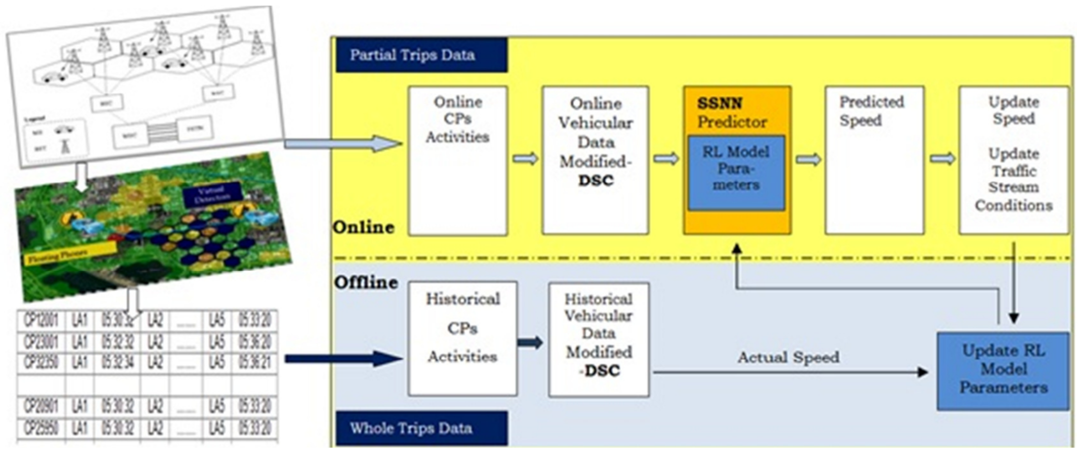

Figure 1: Research Methodology Flow Chart

Modified DSC for Online Clustering CPs into Vehicles

DSC algorithm belongs to the family of Swarm Intelligence (SI) algorithms and is used to cluster CPs aboard of a vehicle to extract vehicular data. DSC as an SI algorithm is known for its robustness and stochastic search nature. DSC doesn't require the previous knowledge of the number of clusters, which is mandatory for the proposed procedure as no secondary monitoring system is used. DSC was originally introduced by Veenhuis & Koppen by combining both Particle Swarm Optimization (PSO) and Flock Algorithms. DSC divide a

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mixed set of data into homogenous clusters (sub-swarms) based on the similarity between the data within each sub-swarm. Similar objects get closer to each other in the datoid space even if they were not close in their attribute space. A set of spatiotemporal data of CPs aboard of travelling vehicles were mapped as a mixed swarm containing sub-swarms of CPs aboard of the same vehicle by Basyoni & Talaat in 2014 (14). The similarity between CPs was based on their spatiotemporal values along a predefined trip. CPs aboard of the same vehicle have the maximum similarity. The DSC algorithm originally consists of 3 phases; Initialization, Iteration, and Cluster Retrieval (23). Superior results were obtained by adding a pre-activation stage based on the similarity values and the distances between the data. Particles that have a minimum similarity value and a minimum distance from the selected particle are only activated (14). However, the model can work for offline systems only as it is built on filtered trips completed between a defined origin and destinations (vehicles reached the destination).

In this model, CPs are clustered from uncompleted trip-data of an uninterrupted section of the corridor. Thus, each CP is represented by a minimal number of LAUs. The receptor function was updated to measure the maximum possible Euclidean distance between two CPs' handoffs at a certain location and the differences in the total travel time of CPs aboard of the same vehicle. The modified DSC algorithm was trained on 26th of July data set. The evaluation measures were used; GEH value, 3 MAPE values of correct vehicle (cluster) occupancy (size), correct number of vehicles (clusters), and CPs clustered to correct vehicles.

Study Case

The model of the 26th of July corridor in Egypt previously developed using PARAMICS traffic micro-simulator by the Center for Intelligent Transportation System (CITS) at Nile University (NU), Egypt is used. The model was augmented by cellular data. Handoffs locations are set every kilometer based on field engineers working at that location feedback. A random cell boundary variation noise was deliberately introduced to consider any slight spatiotemporal variations (about meters and secs) (14). The vehicles travelling from October Governorate to Lebanon Square are traced between points A & B as which defines a section with uninterrupted flow. The section possesses 3 LAs with 4 handoffs as depicted in figure 2.

Figure 2: Uninterrupted section on 26th of July Corridor

CP data were simulated through an ad-hoc procedure that is based on the specification of a number of aboard CPs according to each vehicle type and based on a uniform probability distribution. Based on the high penetration rates of CPs that reached 96.57% in 2011, an

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assumption was made: almost every traveler is carrying only one CP. A warm up period was set to load the model. 3,251 vehicles were released during 8 hours. The released vehicles data were augmented into CPs data using uniform probability distribution with ranges of: one to 5 for passenger cars; one to 3 for trucks; 7 to 15 for minibuses; and 25 to 80 for buses (14).

Discussion and Results

The model extracted vehicular counts with temporal dimensions from uncompleted trip data with very comparable accuracies. The average GEH value reached 0.27±0.24, and the MAPE values for the percentage of correct vehicle (cluster) occupancy (size), correct number of vehicles (clusters), and CPs clustered to correct vehicle are 94.81±2.28, 95.65±3.55, and 97.82±2.43 respectively. An expected slight decrease from the offline setting presented by Basyoni & Talaat occurred as depicted in Table 1. The number of clustered vehicles from the online model was less by only 90 vehicles which is quite acceptable over duration of 8 hrs.

Table 1: *Comparison between the Performances of Vehicular-data Extracted from Whole & Partial Trips'*

	Complete Trip		Partial Trip		Difference	
Measure of Performance	Average	STD	Average	STD	Average	STD
Correct no. of CPs per Vehicle (Cluster) %	98.96	1.09	94.81	2.28	-4.15	1.18
Correct no. of Vehicles (Clusters) %	97.84	2.52	95.65	3.55	-2.19	1.03
Extracted no. of Vehicles	3,175	-	3,085	-	-90	-
CPs Clustered to Correct Vehicle %	99.39	0.8	97.82	2.43	-1.57	1.63
Fitness	0	0	0.02	0.12	0.02	0.12
GEH	0.13	0.15	0.27	0.24	0.15	0.1

Conclusions

Sustainable traffic monitoring systems should be introduced especially in developing countries, as Egypt. The utilization of cellular networks for traffic data collection is a good candidate for such systems. Modified DSC algorithm extracted vehicular data for uncompleted trips with comparable performances to that from complete trips, paving the road to prediction tests. However, continuous research and development is needed to enhance the accuracy of the extracted data. A major concern in Egypt is the legislation considerations for obtaining CP data in real-time from networks providers. In addition, acceptance of tracking CPs in anonymous modes during the current political circumstance is very crucial.

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The Norwegian zero emission neighbourhood Aadland

Speakers:

Risholt, B. [1] , Kristjansdottir, T. , Thomsen, J., Haase, M. and Dokka, T. H.

[1] SINTEF Building and Infrastructure

Abstract: *The ambition level for the zero emission neighbourhood Aadland is that the area will be self supplied with both thermal and electric energy. This paper presents how emissions from operation of the 500 dwellings are offset by on-site renewable energy production. The paper also describes a procedure for how to deal with embodied emissions from materials in an early stage design phase. The study verifies that it is possible to reach a zero emission balance for the neighbourhood. Zero emission from operation is achievable as an average for the neighbourhood. For individual zero emission buildings this also includes embodied emissions from materials and construction in a lifecycle perspective. Qualitative requirements for emissions from materials are defined for all buildings in the neighbourhood.*

Zero emission buildings, renewable energy, sustainable neighbourhood, energy concept

Background

The Aadland neighbourhood is located close to the city of Bergen, Norway and is developed by the company ByBo in close cooperation with the Norwegian research centre Zero Emission Buildings [1]. The ZEB centre was established in 2009 and its objective is to develop competitive products and solutions for eRishoxisting and new buildings that will lead to market penetration of buildings with zero greenhouse gas emissions related to their production, operation, and demolition. The ZEB centre is an interdisciplinary research centre including research on advanced materials, building envelope design, renewable energy production on site, technical systems, users and operational issues. Aadland is one of 7 pilot buildings of the research centre for demonstrating the research results.

The Aadland site close to Bergen was identified as a suitable site for a zero emission neighbourhood[2]. The site is unbuilt land that requires minimal intervention to allow the construction works, no land deposit for masses will be required, surplus electrical energy produced on site may be delivered to the grid and the area has good access to sunlight. The municipality of Bergen is currently preparing a zoning plan for Aadland, and the construction of the first residential buildings will start in 2015. This paper describes the results from the interdisciplinary work in the early program phase for the area`s development and the study of two alternative energy concepts that was carried out in 2012 and 2013.

Guidelines published by the ZEB centre on how to document that a building is a zero emission building are the basis for analysis and planning of Aadland [3]. The guidelines are based the EPBD recast [4] and on international studies in the framework of the IEA SHC Task 40 [5] such as Marzal et al [6].

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Aadland facts

The neighbourhood will consist of several types of multifamily residential buildings built in 2 – 4 floors. The building envelopes are well insulated according to the Norwegian passive house standard[7]. Natural ventilation in summer is supplemented with balanced ventilation with heat recovery in the cold season. No cooling is necessary. Heat is produced on-site, and two alternatives for heat production are analysed, one with ground source heat pumps and one with a biogas cogeneration machine. For both energy production scenarios solar cells are mounted for renewable electricity production. The all electric alternative is well documented internationally [8].

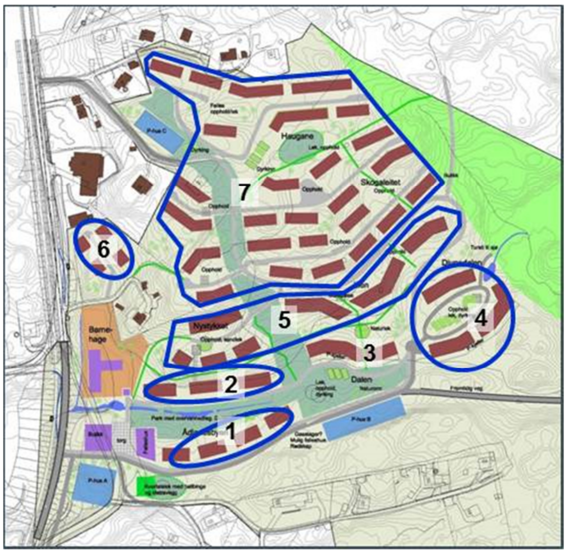

Figure 1 Overview of the Aadland residential neighbourhood with the 7 different building typologies, see table 1

Figure 1 presents how the neighbourhood is divided into 7 areas with different building typologies[9]. Basic facts on the buildings in the different areas are summarized in table 1 below.

Table 1: Overview of the number of buildings, number of dwellings, total floor area as well as the available south faced roof area in Aadland

Aadland area	Floor area m2	No. of buildings	Building footprint Width x length m	No. of dwellings	No. of floors	South faced roof area (m2)
1	2800	4	30 x 10	32	2,5	838
2	3840	3	32 x 10	42	4	693
3	3840	3	32 x 10	42	4	693
4	6090	3	52,5 x 10	78	4	1062
5	11240	7	56 x 10	133	4	2031
6	1000	4	19 x 10	8	2	348
7	16900	26	12,5 x 10	156	2,5	4966
SUM	45 710	50	33 x 8	491	-	10 631

The CO_2 emissions from the buildings will be offset by renewable energy production on-site. The ambition level for Aadland is that the neighbourhood shall be net zero energy, meaning that there shall be no emissions from operation of the buildings (ZEB-O). This is the average for the neighbourhood. In addition, some buildings shall be zero emission buildings including embodied emissions from materials and the construction process in a lifecycle perspective (ZEB-COM).

Qualitative requirements for materials are defined for all buildings in the neighbourhood. The carbon emissions will be calculated for all buildings based on the principal framework of EN 15978[10]. Information from Enviromental Product Declarations (EPDs) will be gathered for materials and products. Where EPDs are not available, data from Ecoinvent database v.2.2 [11] will be used in the analysis. Evaluations of alternative design and material choices will

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be made for the foundations and bearing structures as well as for the underground parking spaces. Possibilities to use reused and recycled materials will be assessed, as well as the availability of locally manufactures materials and products.

Method

The emissions linked to different stages of the buildings' life cycle will be offset by renewable energy production on-site[3, 8]. The study of the Aadland is done for 50 buildings with 491 dwellings, see table 1. The energy calculations are done for the individual buildings, but the results are presented as average values for the entire Aadland neighbourhood where the energy and corresponding CO_2 emissions are normalized using the total living area, see table 1.

Two alternative concepts for renewable energy production on-site are evaluated, see table 2: The first is an all electric solution with roof mounted solar cells for electricity production. The second is a combined solution with solar cells and a bioCHP machine for electricity production.

Table 2 Two alternative energy concepts for the Aadland neighbourhood

Technology	Alternative 1	Alternative 2
Heating including domestic hot water	Solar collectors and heat pump	Solar collectors and biofueled combined heat and power (bioCHP)
Electricity production	Photovoltaic	Photovoltaic and bioCHP

Energy calculations and simulations were performed to analyse if it is possible to build a zero emission neighbourhood. Energy calculations are conducted according to NS 3031 and NS 3700 [7, 12]. Energy performance is calculated stationary giving monthly values according to NS-EN ISO 13790 [13]. The software SIMIEN [14] is used for calculations. SIMIEN is verified for calculation according to NS 3031:2007 and Norwegian Building Code requirements[15]. Calculations on solar energy systems are performed using the software PolySun and PV syst [16, 17]. All energy calculations are using climate data for Bergen, Norway.

The emission calculations are carried out according to Dokka et al [3]. The ZEB-O ambition level includes all emissions from operation such as heating, domestic hot water, lighting and appliances. The next level termed ZEB-OM also includes embodied emissions from the production of the material and products while ZEB-COM also includes emissions from construction. The analysis of carbon emissions from the materials are based on the framework of the EN 15978. [10]. A CO_2 factor of 132 g/kWh is used for electricity and 25 g/kWh for the bioCHP [3].

Results

The calculated energy requirement for the area is presented in in figure 2. The heating demand including DHW (domestic hot water) and space heating constitutes approximately 2/3 of the total energy requirement.

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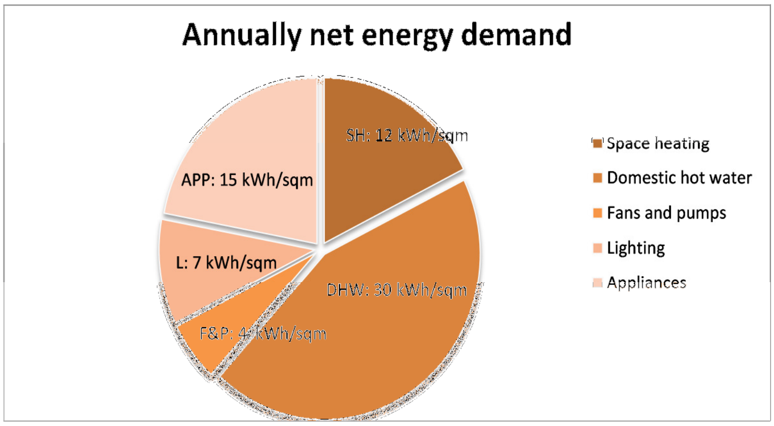

Figure 2 Annual net energy demand for the Aadland neighbourhood. The values are normalized per m2 floor area

The rest of the result section will present the two alternatives for heat and heat/electricity production that are shown in table 2. For the alternative 1 the calculations are based on a local energy supply system per building with a solar collector and a ground source water-water heat pump. The calculations show that a solar collector area of 5.5 m2 per 100 m floor area is sufficient to cover 39 % of the annual need for heating when including DHW and space heating. The heat pump covers the rest of the heating requirement (61 %) with a COP for the heat pump of 2.7. The combined solar collector and heat pump system has a calculated COP of 4.1.

According to the ZEB-O ambition level for the area, CO_2 emissions related to operation of the buildings must be compensated for by renewable energy production. The entire electricity demand for the neighbourhood will be covered by PV electricity production for alternative 1. The calculations show that it is possible to reach a net zero energy balance for the neighbourhood. The results are presented in figure 3 as CO_2 emissions from operation of the dwellings. For alternative 1, the entire roof area of 10 600 m2 is required for solar cells. This means that an additional area of 2500 m2 is required for solar collectors.

Alternative 2 utilizes solar collectors that are installed on each building with a local storage tank. Solar cells are mounted on the roofs. The bioCHP unit constitutes an energy central for the area. The solar collector system is the same as for alternative 1 and covers 39 % of the heating need. In the months June-August the solar system with solar cells and solar collectors cover the heating and electricity need. The rest of the year, it is a combination of a solar system and the bioCHP unit that cover the energy requirement.

Table 4 Annual renewable energy production for energy concept alternative 2

	Solar collector	bioCHP heat	bioCHP electricity	PV electricity
Annual renewable energy production [MWh]	847	1347	857	570

Figure 3 shows the CO_2 balance for alternative 2. The results indicate that it is possible to reach the net zero emission balance for the entire neighbourhood. A PV area of 9 m2 per dwelling is required for alternative 2. This means that there is available roof area for the necessary quantity of solar collectors.

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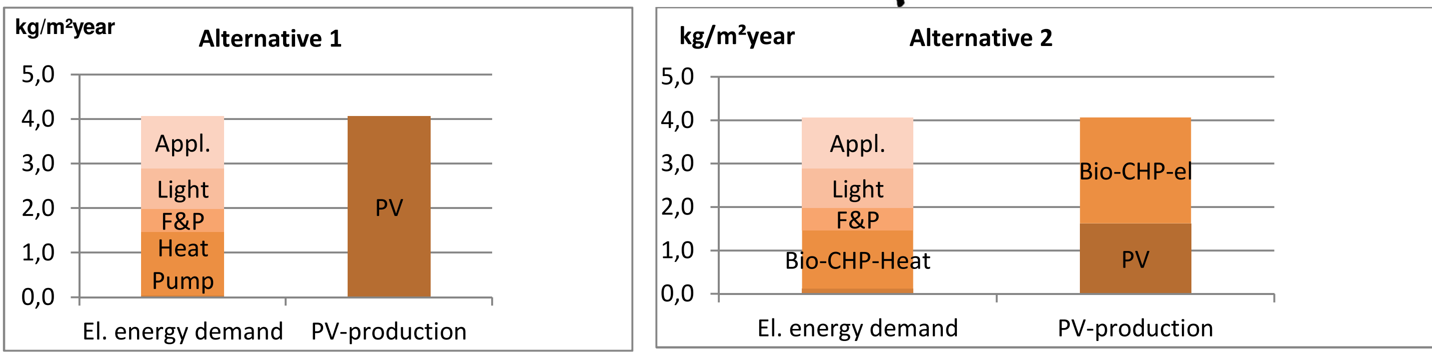

Figure 3 Annual CO_2 balance for the energy concepts alternative 1 and alternative 2.

Figure 4 shows the monthly mismatch between electricity production and electricity need over the year for both alternatives. For alternative 1, the PV electricity production will be higher than the demand in the period April – August and the neighbourhood will export electricity to the grid. The rest of the year the neighbourhood will depend on purchasing electricity. The alternative 2 energy concept gives a monthly electricity production where the solar system dominates in the summer months while the bioCHP energy central covers most of the energy requirement in the cooler season. The neighbourhood has an electricity production that is higher than the demand, so that the neighbourhood is a plus energy neighbourhood and exports electricity to the grid.

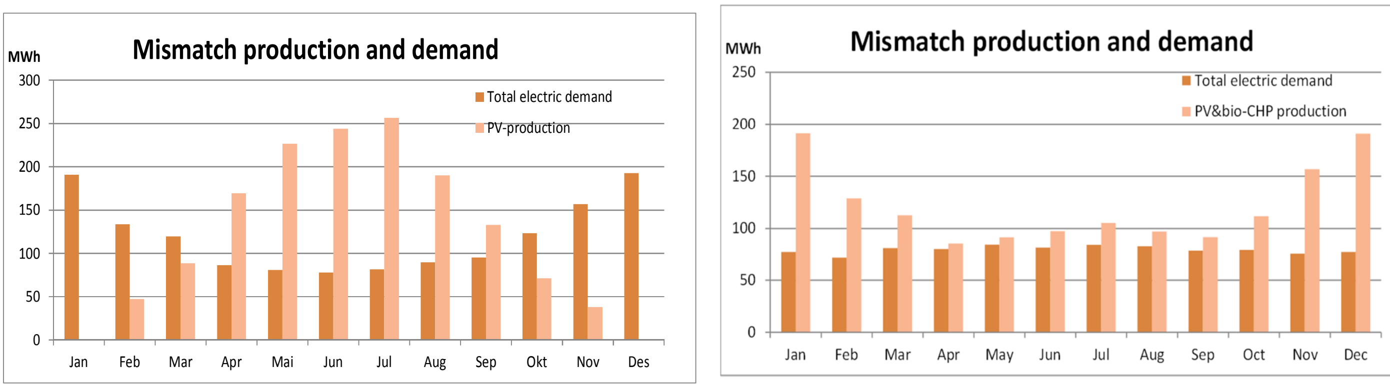

Figure 4 Monthly electricity production and demand for alternative 1 and 2

Discussion and conclusions

The ZEB-O ambition is fulfilled for both the alternatives. This means that it is fully possible to achieve a net zero energy performance for the entire Aadland neighbourhood even in a cold north European climate. However, for alternative 1 additional roof area is required for mounting of solar collectors. For instance PV modules or solar collectors can be mounted on roofs over parking areas. However, the energy analysis shows that alternative 2 is a more robust alternative concerning the energy balance.

Both the alternatives 1 and 2 utilize solar cells for electricity production. The maximum total annual electricity production utilizing all south faced roof area is estimated to 720 MWh. Area 1, 6 and 7, see figure 1 and table 1, are buildings in 2 – 2.5 floors. For these building

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typologies the electricity production corresponds to an annual value between 43 – 50 kWh/m2. The four storey buildings only have a production of 25 kWh/m2. The ZEB ambition for Aadland is that some individual buildings also shall be zero emission buildings, including embodied emissions in materials and emissions from construction of the building (ZEB-COM). The potential for electricity production per square meter floor area is highest for the buildings with few storeys. Therefore, these buildings are selected for further study of detailed design that fulfils the ZEB ambition level ZEB-COM.

A clear difference between the alternative 1 and 2 is shown in figure 4 regarding the mismatch between the electricity demand and the electricity production. Alternative 1 is balanced over the year, but requires import and export of electricity to the grid. The alternative 2 energy concept results in an electricity surplus for all months. Both alternatives require the local energy company is involved in the planning to make sure that the grid can take up the electricity for export. Otherwise there will be a need for other solutions as electrical car hubs or battery solutions to store the electricity surplus.

The property developer ByBo decided to go for the ZEB ambition level for Aadland before selection of the site and site development. The Aadland early stage planning has been organized as multidisciplinary workshops. The property developer, architects, civil engineers, energy advisors and lifecycle analysis experts from the ZEB centre have worked together to develop innovative concepts to realize the high ambitions. One outcome is that the shape of the buildings and roof angles has been optimized to harvest solar energy. Another example is the analysis to find the optimum between reducing the energy requirement through passive measures as improved insulation and natural ventilation, and active technologies such as solar collectors and heat pumps. The interdisciplinary approach gives an effective process with good communication.

The early phase analysis of energy concepts that are reported in this paper has not included an analysis of the materials and embodied emissions nor the emissions from construction. However, the discussions in the workshops have resulted in guidelines regarding materials. Calculations of embodied emissions from materials shall be performed for all buildings. Embodied emissions shall be evaluated for all materials to make the best choices. One example would be to use low carbon concrete instead of traditional concrete with higher emissions.

The ambitious goals regarding energy performance and emissions will be a driving force to enable innovative design of buildings, push technology forward and give specialists from different disciplines the possibility to co-operate. The process will be a valuable experience for all involved actors with regard for future projects with high ambitions.

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Criteria for energy efficient urban planning

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Abstract: Many cities today are committed to increase the energy efficiency of buildings and the fraction of renewables especially in new urban developments. However, quantitative data on urban energy performance as a function of urban density, building compactness and orientation, building use and supply options are rarely available during the design of new cities or early scenario analysis for existing city quarters, making it difficult for cities to effectively evaluate which concepts work today and in the future. The paper proposes a methodology to assess the energy demand and supply options as a function of the availability of geometry, building standard and use data. An automated procedure was implemented to identify each building´s geometry and volume and transfer the information to a simulation tool, which then calculates heating demand and solar energy generation on roofs and facades. The simulation include shading calculations for each segment of the façades and roofs and thus allows a very detailed quantification of the urban energy demand.

By applying the methodology to a case study city quarter designed in an urban competition in Munich, it can be shown how the urban design influences the energy demand of the quarter and which fractions of renewable energy can be integrated into the roofs. While the building insulation standard and use are the is most important criteria for building energy efficiency (with an impact of more than a factor 2), the exact geometrical form, compactness and urban shading effects influences the energy demand by 10 to 20%. On the other hand, the detailed roof geometry and orientation influences the possible solar coverage of electricity or thermal needs. Zero energy city quarters with solar resources alone are only possible when all available building surface areas are fully optimized and do not need to fulfill other requirements such as providing roof gardens, terraces or others. Combinations with other more centralized renewable resources such as deep geothermal, solar or biomass heat or cogeneration plants are often necessary to achieve zero energy balances.

Keywords: urban energy system design, energy assessment tools, 3D city modelling

Introduction

Sustainability certification schemes have recently extended to the urban level, mainly to improve awareness and publicity for the developers. Simple assessment rules rules prevail to evaluate a city quarter performance. Haapio (2012) analyses existing assessment tools for urban communities, namely the Japanese system CASBEE for Urban Development, the UK certification scheme BREEAM Communities and the US rating scheme LEED for Neighbourhood Development. In all three rating schemes, infrastructure aspects dominate the criteria with 24% (BREEAM), 32% (LEED) oe 45% (CASBEE) weight, while ressources and energy only amount to 14-18%.

For a more quantitative evaluation of a city quarter energy performance, a more precise buildig typology or simulation based approach has to be chosen. A review paper on urban energy models clustered urban simulation papers in six categories, ranging from technology, building and system design to urban climate, policy assessment and trasnport (Keirstead et al, 2012). While detailed physical models dominate the technology and building simulation tools, the system design models are mainly optimisation tools with very simple component and building models on a district scale with the goal to minimize costs for energy infrastructure and building effiency.

Between simple certification schemes, local energy planning tools and detailed individual building simulation there is still a knowledge gap of how the design of an urban quarter affects the energy performance and the potential for renewable integration.

In this paper a methodology is developed and implemented to analyse under which conditions a city quarter can cover its building energy requirements with renewable sources and which data needs to be available to seriously assess energy demand and production. Transport energy is excluded from the analysis, as it requires completely different modelling tools for the demand evaluation and as renewable fuels are most likely to be produced more centrally than on the urban surface itself.

For a case study in Munich/Germany criteria were proposed for urban energy efficiency in the early design and competition stage of a new city quarter and the analysis of a neighbouring existing city quarters, which was used for the model validation. In a second stage, more detailed quantitative analyses of building block clusters are done to show the influence of urban structure on energy performance and renewable integration potential.

Criteria for energy efficient city planning

To assess the energy performance of city quarters or entire cities, criteria have to be defined as important characteristics for evaluation. Often criterias are grouped in categories of urban assessment, such as infrastructure, transportation, energy and resources. As the goal of this work was to analyse assessment methods only for urban energy, criteria were developed for the energy performance category only. Related to the criteria are corresponding indicators, which describe the quantitative measurements to evaluate the performance.

As the main energy related criteria, four categories were established based on an analysis of many low energy city quarters:

- the integral energy concept with the criteria of innovation and highlight projects
- the induced energy demand with the criteria of urban and building compactness
- the solar access with main orientation of the buildings, minimizing shading and placing low consumption districts furthest away from the district heating plant
- the renewable supply with efficient renewable heat distribution and photovoltaic panel integration in buildings

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For the four categories, indicators were developed, which are partially qualitative, but try to include quantitative information as early as possible in the analysis process.

Case Study Munich Freiham Urban planning competition

The city of Munich/Germany plans a major expansion to the west of the city named Freiham to be developed during the next 30 years. The urban extension has a total area of 350 ha with a northern part of mainly residential buildings and a southern part with mainly business, shopping and the city center. Comparably high renewable heating fractions of 90% will be obtained by a deep geothermal heating plant, while electricity production relies on decentral photovoltaics. An urban planning and landscaping competition for the first stage of construction in the Northern section of Freiham has taken place in 2011. The criteria and indicators were analyzed to evaluate the energy performance of the urban plans.

The analysis showed the limits of assessing energy performance based on paper plans still typical in urban competitions. Many criteria such as urban and building compactness could only be estimated, as well as solar access and mutual shading of buildings, as these required data were not provided by the participating urban planning offices. For the residential sector, the list of criteria and the maximum achievable number of points are shown in Figure 3 together with the result analysis of the 14 competition contributions. From the 1000 total points the best proposal reached 765 points, the worse 250 points.

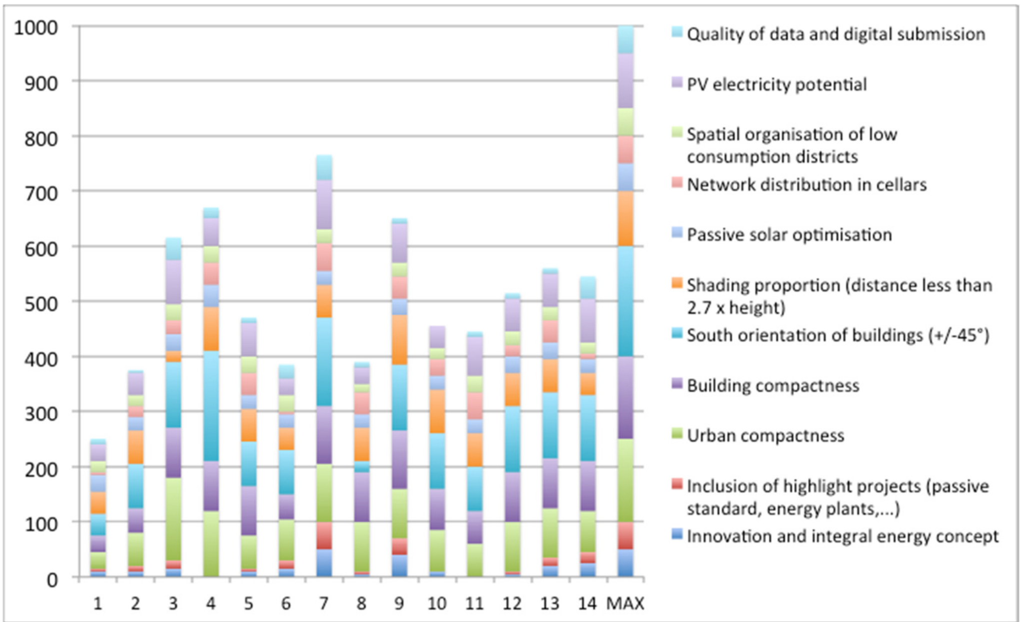

Figure 3: Maximum number of points achievable for each criterium in the right column and results for the 14 submitted competition proposals in the residential area.

The proposal number 1 finally won the urban competition, mainly due to the fact that it corresponded best to the urban planning idea of a green garden city, not for its energy concept.

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Building cluster analysis for detailed impact evaluation of urban form on energy demand, renewable supply and building costs

To quantitatively analyse the influence of the urban form on building efficiency, renewable integration potential and building costs of several building energy standards, one of the clusters of the winning urban plan with multi-family buildings was selected for a detailed analysis. Four different urban forms were developed with the planning office west 8 and subsequently simulated. All concepts (nearly) have the same floor space number (GFZ) of 1.4. The variants can be distinguished into open block edge (B) and (closed) block edge types (C). Another difference was the roof structure: Compact flat roofs (B.2, C.2) compared to roofs with roof terraces and corresponding roof structures (B.1, C.1). For each form three building energy standards were calculated. EH 70 corresponds to 70% primary energy demand compared to the legal standard EnEV 2009, EH 55 to a maximum of 55% and the most efficient standard EH 40 to 40%.

The combination of the four cluster variants and their three building energy standards were converted into a 3D city model. This model allows a computerised procedure for calculating the heating energy demand according to DIN V 18599 and to determine the influence of higher building energy standards through thicker walls on net floor area losses (and reduction of the marketable area) and building costs. Additional, options of photovoltaics usage were analyzed to determine the possibilites to cover the electricity demand with clusterwide self produced electrical energy.

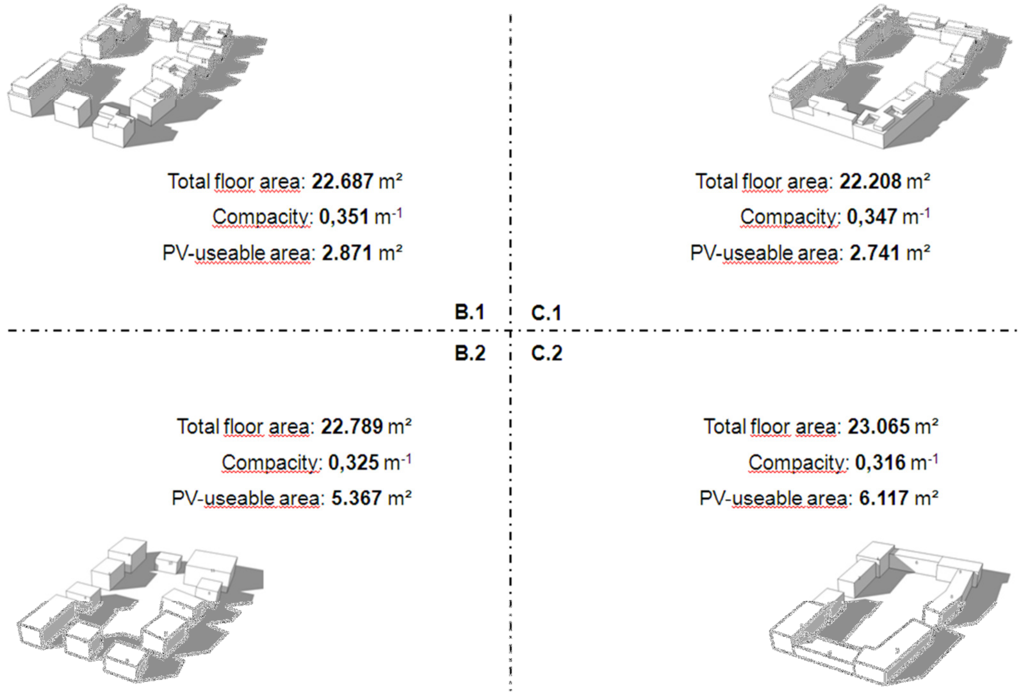

Figure 4: Considered building und urban form variants

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Results for heating demand and costs

The heating demand was simulated using the monthly energy balance method described in DIN V 18599-2 and implemented in the simulation environment INSEL (www.insel.eu). The results showed that the urban form was less important for the heating demand than the building compactness. With more compact buidings, the demand decreases by about 10% (heating demand difference between variants *.1 and *.2), while the detailed urban form (B.* versus C.*) only changes the overall demand by 1 to 2% (see Figure 5).

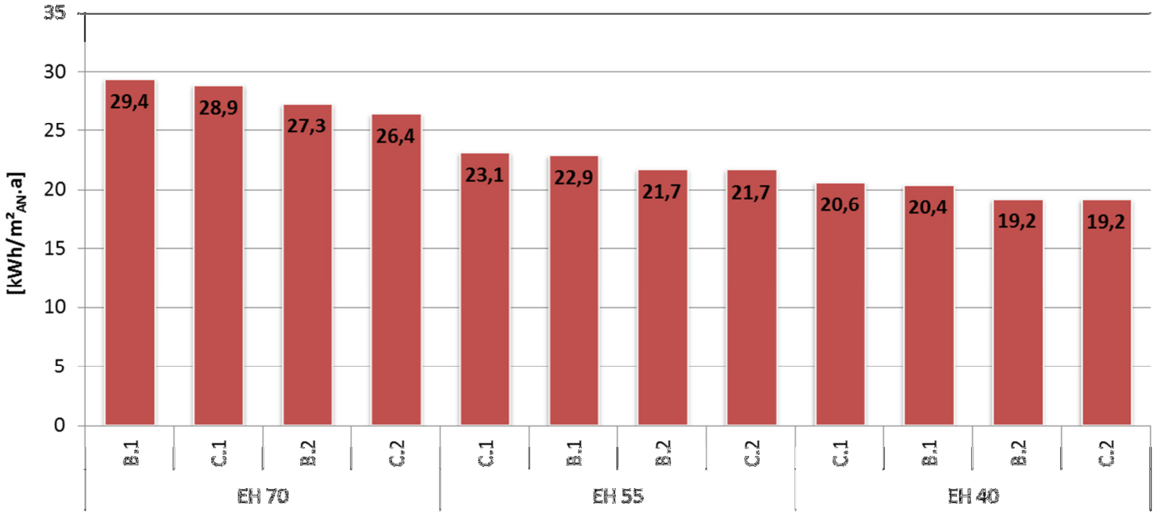

Figure 5: Comparison of specific heating demand of all cluster forms for three different building energy standards.

Building compactness and building costs are closely linked. According to Figure 6, additional building costs for more efficient energy standards can nearly be offset by an optimized cluster form. For example, the building costs for combination B.1/EH 70 are comparable to cluster form C.2/EH40. That is why the optimisation of the cluster form represents an important step towards reduction of building costs.

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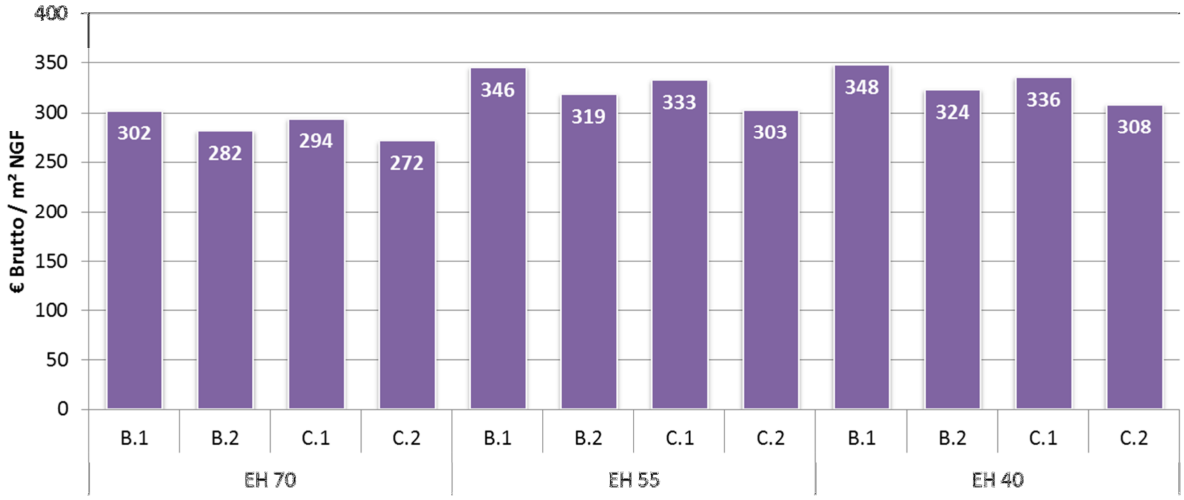

Figure 6: Comparison of building costs per m² net floor area

PV potential and coverage rate of self-produced electricity

By planning a construction site or cluster, the fact that roof structures and roof terraces increase the heating demand of a building in principle or increase the costs to eliminate these disadvantages should be kept in mind. Moreover, roof structures minimize useable area for PV modules. However, the question of roof area usage must also consider aspects of higher levels of housing quality through roof terraces or roof greening.

For all cluster forms a PV potential study was undertaken. Within this study two different possibilities of PV installation (FDA = flat roof with inclined PV modules) and PDD = mono-pitch roof) have been investigated. The analysis is based on polycristalline silicon modules with 15% efficiency and 10% electrical system losses. To calculate the electricity coverage rate for each cluster form, a household-specific electricity demand of 20 kWh/m² was assumed.

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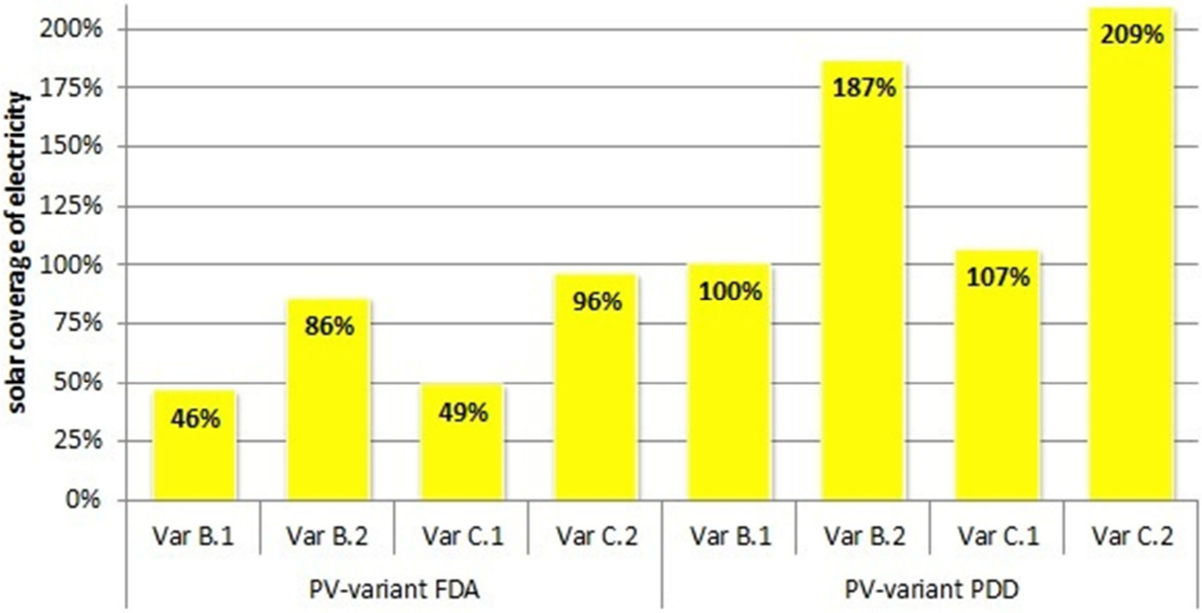

Figure 7: Clusterwide PV potential and coverage rate of self-produced electricity

As shown in Figure 7, the installation of PV modules on mono-pitched roofs (PDD) could cover the electricity demand for all building variants. Yields of inclined PV modules on flat roofs (FDA) are low compared to the PDD-installation and can not cover the complete cluster electricity demand.

Conclusions

The paper presents a methodology to evaluate the energy performance of urban quarters at different stages of design and analysis. While mainly developed to compare urban planning competition results for a large city extension in Munich/Germany, it can also be applied to existing city quarters with scenarios for rehabilitation and energy infrastructure improvement. The main goal was to establish an accurate energy performance prediction method to compare urban development types.

The analysis of today´s urban planning competition assessment showed that only a very general evaluation of an urban design´s energy performance is currently possible and estimated energy performance is rarely taken as a major criterium in urban competitions.

The detailed cluster analysis emphasised that it is very important to analyse the detailed building form, as the loss of building compactness increases the energy demand for heating by 10-20% while it reduces the integration potential of renewables by more than 50%. Different urban forms for otherwise compact buildings only influences the heating demand by 1-2%. Costs and building compactness are closely linked and additional costs by higher building standards can be compensated by more compact structures. The cluster analysis also showed that 100% or more PV electricity can only be generated if mono pitched roofs are fully covered with photovoltaic modules.

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